ENERGY EFFICIENCY

TECHNICAL INFORMATION

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ENERGY EFFICIENCY

THE AIR BARRIER — ONE OF THE MOST CRITICAL ELEMENTS IN THE BUILDING ENVELOPE

The windows, doors, walls, and roof all make up the building envelope that separates the indoor environment from the outdoors. Although the building envelope serves many purposes, one of its most important functions is to reduce the air leakage in the building. Air leakage not only has a large impact on the energy and maintenance costs in a building, but it can also affect the indoor air quality and the occupants' thermal comfort.

This fact sheet outlines the importance of reducing the air leakage in a building. The general causes for air leakage in a building and the ways of reducing it are described. Although good initial design and construction of an air barrier are the best ways of ensuring low air leakage in a building, it is possible to improve the air barrier in existing buildings. Some methods for identifying air barrier problems are listed along with examples of some building envelope improvements.

WHY REDUCE THE AIR LEAKAGE IN A BUILDING?

The building envelope has many functions. It provides strength and rigidity while providing a barrier to fire, solar radiation, noise, heat transfer, water, vapor and air leakage. Reducing the air leakage is one of the most critical elements of a building envelope, since it affects:

- the energy costs to heat and cool the building;
- the costs of maintaining the building envelope;
- the indoor thermal comfort for occupants; and
- the indoor air quality.

1. Energy costs

Air leakage can have a large impact on the energy costs for both heating and cooling a building. In the winter, exfiltration (air leakage out of the building) is like throwing money right out of the building. The warm air lost to the outdoors must be replaced with cold air which has to be heated to room temperature. Assuming that the air has to be heated from 0°C to 20°C, 24 kilowatts of power would be required for every 1000 litres per second (L/s) of air exfiltrated. Over four months, this 1000 L/s of air leakage would total approximately

70,000 kilowatt-hours of wasted energy, not including the additional energy required to humidify the cold, dry outdoor air. Similarly, in the summer air leakage increases cooling costs by increasing the energy required to cool and dehumidify the air being delivered to the building.

As will be described later, air leakage rates are often highest when the outdoor temperatures are coldest and the heating loads are already at their highest. If the heating equipment is electrically powered, air leakage will push peak demands for electricity even higher. Electric utilities charge commercial customers heavily for peak electricity demands. A commercial customer will often have to pay for that peak electricity demand not only for that monthly bill, but for the next eleven months. (Refer to the fact sheet on "Utility Rates and Billing Practices" for a complete explanation of electricity demand charges.)

2. Maintenance Costs

Air is capable of holding a great deal of moisture: one kilogram of air at 21°C and 40 per cent relative humidity contains over six grams of water. In the winter, when air leaks out through the building envelope, it cools down and is no longer able to hold all of this moisture. If the air cools down to 0°C, the maximum amount of water it can hold is four grams for every kilogram of air. In other words, at least two grams of water must be left behind. If this water condenses in the building envelope, it may cause rotting, or mold and mildew growth. Water damage will reduce the life of the building materials and result in higher maintenance costs. The best way to avoid water condensation in the building envelope is to reduce the air leakage.

3. Indoor Thermal Comfort

In the winter, air leakage may cause cold drafts around the building perimeter. Consequently, occupants may turn up the thermostat, which may cause overheating elsewhere in the building. As well, air leakage affects the indoor humidity. In the winter, the leakage of cold dry outdoor air reduces the indoor humidity, while in the summer the indoor humidity may be increased.

4. Indoor Air Quality

Contrary to popular belief, a leaky building does not always have good indoor air quality. In fact, air leakage can contribute to poor indoor air quality. Indoor air quality problems are the result of contaminant sources and/or poor ventilation; air leakage rates can contribute to both of these issues. As described earlier, air exfiltration may cause condensation in the walls which leads to mold and mildew growth. If the pressure across the building envelope changes, perhaps due to changes in the wind, air infiltration may draw the molds and mildew into the building, reducing the indoor air quality. As well, many buildings have parking garages attached at their lower levels where, as described later, air infiltration is most likely to occur in the winter. Air infiltration from parking garages can contribute to high levels of carbon dioxide, carbon monoxide and other contaminants. Aside from increasing the indoor air contaminants, air leakage reduces the effectiveness of the ventilation system which is supposed to deliver clean air to the occupants. The uncontrolled air movement caused by air leakage changes the air pressure distribution in the building. The ventilation system's normal air flow patterns are impeded; thus, clean ventilation air may not reach all parts of the building as intended.

CAUSES OF AIR LEAKAGE

In order for air to leak across a building envelope, two things are required: a pressure differential and an air leakage path. Just as heat flows from a high temperature to a low temperature, air flows from a high pressure to a low pressure, but there still has to be a path for the air to follow.

Three main factors influence the pressure differential across a building envelope: wind, the mechanical ventilation system and the "stack" effect.

a) Wind

Wind induces positive pressure on the windward side of a building and negative pressure on the leeward side. Wind gusts can cause large fluctuations in the pressure difference across a building envelope.

b) Mechanical ventilation system

The mechanical ventilation system consists of large supply and exhaust fans. If more air is brought into a building than exhausted, the interior of the building becomes pressurized.

c) Stack effect

In large buildings, the most dominant cause of pressure across the building envelope is the stack effect, whereby warm air being lighter than cold air, rises. In the winter, the warm air inside the building rises relative to the cold outdoor air and causes a positive pressure on the top floors of a building. As a result, warm indoor air exfiltrates from the top floors and cold outdoor air infiltrates on the lower floors. The stack effect is worse in the winter, when there is a large difference between the indoor and outdoor air temperatures, and in tall buildings. One can try to reduce the stack effect by sealing the vertical columns in a building, such as the service ducts for wiring and plumbing.

The Air Barrier

Since it is impossible to eliminate the pressure difference across a building envelope, the best way to reduce air leakage is to seal all air flow paths through the envelope. This is accomplished by proper design and construction of a continuous air barrier in the envelope. The air barrier component of the building envelope is identified in the following figures.

As shown by these examples, the air barrier may be made of any type of material that is impermeable to air, such as metal, glass, gypsum board or polyethylene. It is critical, though, that the air barrier be continuous and not allow any paths for airflow across the envelope. This means that care must be taken to design and construct the envelope so that all joints in the air barrier are sealed. Care must also be taken for the air barrier to be properly supported so that joints will not become unsealed when the envelope experiences gusts in wind pressure.

Figure 1a - Gypsum drywall provides the air barrier in this masonry wall

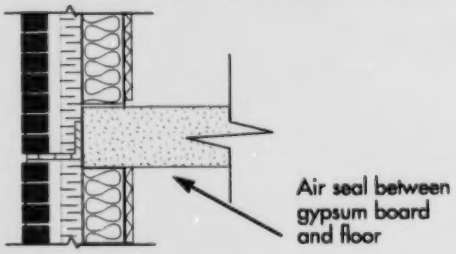


Figure 1b - Metal and glass provides the air barrier in this curtain wall

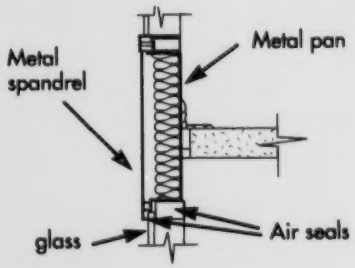
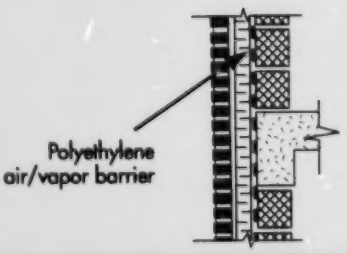


Figure 1c - Polyethylene provides the air barrier in this masonry wall



Addition to "Air Leakage Measurements" section

The American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE) handbook classifies building envelopes as tight, average and leaky if air leakage values are 0.5, 1.5 and 3.0 L/s per square meter of exterior wall area at a 75 Pascal pressure differential respectively. In fact, buildings are often much leakier. A study conducted by the National Research Council (NRC) and Public Works and Government Services of Canada (PWGSC) in the seventies measured the air tightness of six Canadian federal office buildings. The buildings were less than ten years old at the time and were 10 to 26 storeys high, with precast concrete panels or metal panels. The buildings were pressurized using their supply air system with all of the return and exhaust fans turned o£ Air leakage rates of between 1.73 and 4.85 Lls/m2 at 50 Pa were measured, which is about 2.25 and 6.31 L/s/m2 at 75 Pa. (Note: Air leakage rates are not always quoted for the same reference pressure. Be sure to compare measurements at the same pressure difference. As well, remember that the pressure difference actually experienced by the building envelope is continually varying and may be quite different from this reference pressure.)

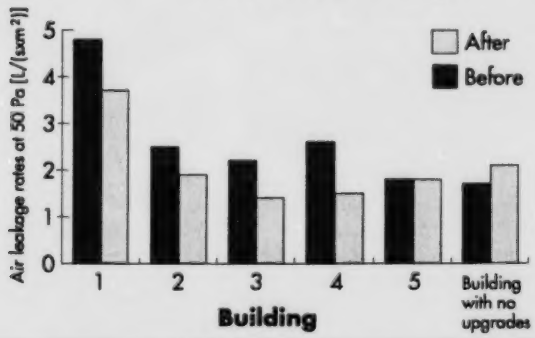
Air Barrier Improvements

There are many ways of analyzing the air leakage in a building aside from full building pressurization tests which can be quite expensive. Visual inspection, thermography, smoke pencil tests, partial pressurization tests and monitoring temperatures, humidity and pressures are just a few of the methods used by building envelope specialists to diagnose air leakage problems. Once the problem is understood, it is possible to determine the most appropriate building envelope improvement.

The following is a list of some upgrades that could reduce the air leakage in a building:

- Seal and caulk curtain wall joints;
- Seal and caulk windows and doors;
- Seal window/wall joints, door/wall joints, floor/wall joints, floor/ceiling joints and other joints;
- Seal pipe, duct and cable holes that are through the floors and exterior walls;
- Seal mechanical rooms in the penthouse, where the stack effect is strongest; and
- Redo the exterior cladding of the building.

Figure 2 - Air leakage test results before and after building envelope upgrades in the NRC/PWGSC study



Building upgrades can reduce the air leakage rates, even in older buildings. For example, five of the six buildings tested by NRC and PWGSC in the seventies underwent various building envelope upgrades. The air-tightness of the buildings were then re-measured in 1991 using the same test procedures. Four out of the five buildings were more airtight the fifth was unchanged and the building that had no envelope upgrades was much leakier.

Conclusions

A good building envelope is critical for maintaining a comfortable work environment in an energy-efficient manner. Although the building envelope has many functions, it is very important that it has a continuous air, barrier. Many effective methods exist for improving the air barrier even in older buildings.

For further information please contact:

Industrial, Commercial and Institutional Programs, Natural Resources Canada.
580 Booth Street, 18th Floor, Ottawa, Ontario K1A 0E4, Fax: (613)947-4121

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Envelope Design Guidelines for Federal Office Buildings: Thermal Integrity and Airtightness, A.K. Persily for the General Services Administration and the U.S. Department of Commerce, National Institute for Standards and Technology, NISTIR 4821, March 1993.

The following organizations also have many excellent publications on building envelopes:

- Canada Mortgage and Housing Corporation
- Public Works and Government Services of Canada
- National Research Council

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Part of the Efficiency and Alternative Energy Program

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ENERGY EFFICIENCY

COGENERATION TECHNOLOGY

Cogeneration is the simultaneous production of electrical and thermal energy from the same fuel source, making for a more efficient, and economical, use of resources than if both forms of energy were produced separately. Cogeneration offers an opportunity to control and reduce energy costs by investing in a highly efficient power plant.

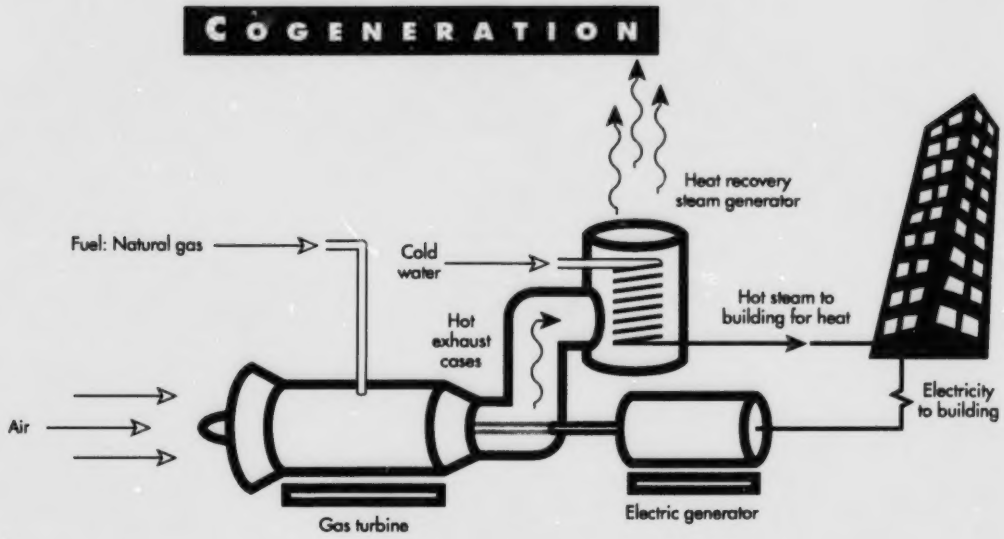
Cogeneration Technology - How it Works

The heart of the cogeneration system is the prime mover. The prime mover (a reciprocating engine or gas turbine engine) consumes fuel which is converted into mechanical energy to drive an electric generator. Most prime movers are inherently inefficient, since they are only able to convert about 30 per cent of the fuel energy into useful mechanical energy. The remaining 70 per cent of the fuel energy is wasted as heat in the engine exhaust or through the walls of the prime mover. The key to cogeneration is its ability to harness this otherwise wasted energy. By using a heat-recovery system, such as an exhaust heat exchanger, steam or hot water can be produced and used for other purposes such as space heating or additional power generation. Included in any cogeneration package is a distribution network for the generated electricity and the steam or hot water. Also required is a control system to monitor and regulate the whole package.

Types of Systems

Cogeneration systems are generally characterized by their prime movers. The three main types of systems applicable to federal facilities are:

- ***Steam Turbine*** systems use the energy in high-pressure steam to power a steam turbine, which in turn drives a generator. A high-pressure boiler is used to generate steam. The turbine is similar to those used in thermal electric generating stations - except that steam is allowed to exit the turbine at a pressure high enough for use in space heating.



- *Gas Turbine* systems use a combustion turbine (similar to a jet engine) to drive a generator. Thermal energy from the hot turbine gases can be recovered in a heat recovery steam generator to produce steam. This is a popular choice because natural gas is plentiful and relatively inexpensive.
- *Reciprocating Engine* systems use internal combustion piston engines as the prime mover. The generator is driven directly from the drive shaft of the engine, and thermal energy (of a lower temperature than from gas turbines) is recovered from the oil cooler, jacket cooling water and exhaust gases. Reciprocating engines are generally more suited to producing hot water rather than steam.

Sizing a Cogeneration System

Before adopting a cogeneration system, the candidate facility's thermal and electrical loads must be carefully analyzed. The wide range of available systems allows some flexibility in matching outputs to existing thermal and electrical loads. Systems are sized by the rated capacity of electrical power production, yet may differ in the ratio of electricity to thermal energy they produce (see below).

For example, steam turbines systems yield approximately two to three times the thermal output of gas turbine units. The flexibility in sizing offered by the various options allows the designer to select a system that operates utilizing the maximum amount of thermal energy.

Electricity and Thermal Energy

Prime Mover	Heat Rate (Btu/kWh)	Electrical Output (kW)
Reciprocating Engines	10,000 – 25,000	10 – 3,000
Gas Turbines	22,000 – 11,000	200 – 5,000
Steam Turbines	50,000 – 30,000	170 – 4,000

This is the single most important operational objective and is based on the assumption that any excess electrical capacity can be sold back to the utility, whereas excess thermal capacity must be dumped and wasted (unless a nearby consumer for the thermal energy can be found).

Other considerations in adopting, sizing, and operating a cogeneration system include the following:

- The conventional cost of purchased power.
- The cost of utility-supplied supplemental, standby and maintenance power.
- The income from electricity to be sold back to the utility.
- The incremental cost of fuel, operation and maintenance.
- The cost of purchasing, installing and commissioning the system
- Administrative costs.

Case Study

The National Research Council is currently in the process of procuring a gas turbine based cogeneration system for their main campus in Ottawa. The system, being built at a cost of $6.3 million, will produce up to 4 MW of electricity and 22,000 pounds of steam per hour. The size of the system was determined by the thermal (steam) requirements of the campus. Financial savings of $1 million per year are expected.

The Benefits

Clearly, the main benefit of cogeneration is that it offers the potential for achieving substantial energy cost savings – from 33 per cent to 50 per cent. Cogeneration can also improve the reliability of electrical energy supply in the form of standby power. Potential revenues can be realized from the sale of electricity to utilities or from surplus steam and hot water sold to neighbouring users. A particularly attractive feature of gas turbine cogeneration installations is their "cleaner" emissions (reduction of NO_x and CO_2) compared to the standard fossil-fuel burning stations.

For further information please contact:
Industrial, Commercial and Institutional Programs, Natural Resources Canada,
580 Booth Street, 18th Floor, Ottawa, Ontario K1A 0E4, Fax: (613) 947-4121

Reference

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Cogeneration Sourcebook, Ministry of Energy, Sept. 1988.
Cogeneration Assessment Guide of Federally Owned Buildings, J.L. Richards & Associates Limited, April 1992.

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ENERGY EFFICIENCY

ENERGY MANAGEMENT AND CONTROL SYSTEMS

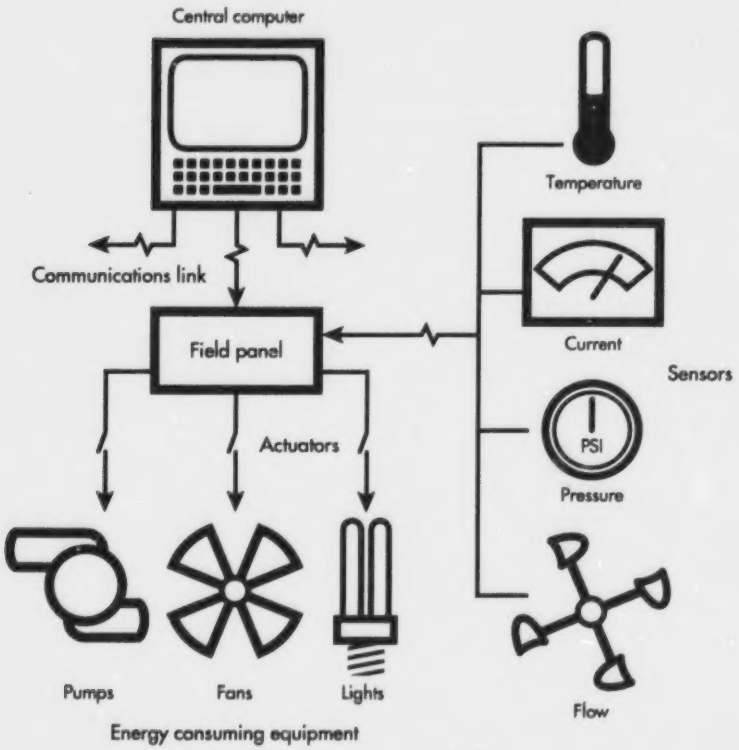
Energy Management and Control Systems (EMCS) are rapidly becoming the optimum choice for effective monitoring and control of energy consumption within commercial buildings. Benefiting from rapid advances in electronic hardware and computer software, the EMCS are a leading candidate for saving operating costs. EMCS reduce energy waste through automatic control of the building's energy-using systems. The main trend is towards integrating the EMCS with a fire/security system and elevator control system to obtain a truly "smart" building automation system.

EMCS Components

Physically, the EMCS is comprised of the following main building blocks:

- ***Sensors*** – sensors and transducers are electronic devices which convert a parameter (physical measurement such as temperature or humidity) into an electrical signal. In this form, it can easily be transmitted to a central processing unit or computer.
- ***Control Actuators*** – are devices that can receive instructions from the main computer and adjust some piece of equipment. For example, it could involve a device that switches a fan motor on and off, changes a damper position, turns lights on/off or adjusts a thermostat.
- ***Communication Links*** – signals or messages are exchanged between the sensor and computer by hard wire, radio frequencies, powerline carrier or fibre optics. Each method of communication must be evaluated separately, keeping in mind such things as equipment costs, labour costs for installation, reliability, etc. Communication technologies with high capital costs may pay for themselves with decreased installation and maintenance costs.

Typical Energy Management System



- ***Computer*** – the central microprocessor is the heart of the EMCS. Its capabilities are extensive and are continually advancing. The software allows the following main functions to be performed:
  - Monitoring of parameters such as temperature, humidity, equipment status, air quality, equipment health conditions, and liquid levels or flow rates.
  - Programming of equipment to stop or start automatically as needed – the key is to determine when and for how long the equipment can remain off without adversely affecting occupants or the building equipment operations. This will vary for each building and equipment configuration.
  - Intervention control allows the computer to override a local system that is performing below optimum due to some fluctuation or disturbance.
  - Alarms can be triggered at predetermined levels to alert an operator of a problem.
  - Logging abilities are a critical capability of an EMCS system. Historical status and performance of a building's systems can be obtained as well the para-

meters of an alarm condition. The EMCS can also provide a preventive maintenance function whereby work orders, parts lists and maintenance procedures can be printed out as required.

Benefits

- ***Minimizes Energy Costs.*** An EMCS can minimize and control the electrical demand within a building by shifting demand in relation to the time-of-use energy rates, or by limiting or shaving peaks to reduce demand charges. The two most common load control strategies are demand limiting and duty cycling.
- With *Demand Limiting*, the EMCS is programmed to monitor the electrical load and make sure it does not exceed a predetermined level. This is achieved by having the EMCS shut down nonessential equipment such as water pumps, ramp and space heating, and any electrical load that can be deferred.
- With *Duty Cycling*, the EMCS cycles electrical mechanical equipment on and off to save energy while maintaining comfort conditions. Since many of a building's systems are designed to handle worst-case situations, the equipment can be turned off intermittently during lower load conditions. Some equipment, such as electrical motors, may have a reduced life when cycled on and off frequently.
- ***More Comfortable Environment.*** Temperature and humidity can be more easily maintained within a desired comfort range, due to more accurate sensors and precise control zones.
- ***Reduction in the Number of Operation, Maintenance, and Security Staff.*** The centrally-based EMCS can monitor and control the HVAC, fire protection, security, lighting and elevator systems. It provides 24 hour observation and can alert an operator to any trouble or problems.
- ***Reduction in Unscheduled Down Time.*** Sophisticated software options schedule and flag maintenance activities to prevent potential problems.
- ***Serves as a Teaching Instrument*** for building operators and property managers.

Experience with retrofitting of existing buildings shows that installation of a new or upgrading of an existing EMCS usually is a measure that offers one of the shortest payback periods.

For commercial buildings of more than 10,000 square meters, the average cost of the EMCS ranges between $400 to $800 per input or output point. Energy savings of 20% are typical and payback periods range from 2 - 5 years.

An EMCS can be applied to almost all new or existing commercial buildings for automating functions previously performed manually. Capital costs for retrofitting an EMCS are generally high due to restrictions imposed by existing controls and HVAC equipment. The

modularity of new sophisticated systems allows the user to expand the system as needed. For example, the user could start off with only HVAC controlling software and add lighting control at a future date. The cost of installation of an EMCS is largely based on the number of connected points specified (i.e., number of sensors and actuators). Usually the EMCS can be specified and installed on a turnkey basis. The training of building operators is an important part of any package.

For further information please contact:
Industrial, Commercial and Institutional Programs, Natural Resources Canada,
580 Booth Street, 18th Floor, Ottawa, Ontario K1A 0E4, Fax: (613) 947-4121

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ENERGY EFFICIENCY

UTILITY RATES AND BILLING PRACTICES

Utility rates are the basis for the energy costs in a building. A good understanding of their structure and application provides insight into the energy use and costs required to efficiently operate a facility. This fact sheet describes the various utility charges applicable to a commercial customer.

Utility Rates — How Are They Set?

Electric utilities have the most diverse rate structures. Commercial customers often have numerous choices as to which rate structure they fall under. The diversity in rate structures reflect the cost for the utility to build power plants and distribution systems, maintain the systems and generate the power.

Keeping this in mind, one can see that there are many factors influencing the type of rate structure selected by a utility. The rate structures can be used to influence energy usage patterns, such as offering lower rates at certain times of day. For the most part, utilities set the rates on a user-pay basis.

Electric Utility Rates

Electric utilities have varied rate structures. A commercial customer can have numerous choices regarding rate structures, due to costs for building power plants and distribution systems, maintaining the systems and using fuel to generate the power.

Demand charge

The size of a power plant helps determine a utility's costs and is determined by the maximum amount of **power*** required at any given time. One can think of power as being like the speed of a car, while the power plant is like the engine of the car. In simplified terms, the bigger the car's engine, the faster the car can travel; but, the bigger engine costs more.

The customer is charged for the maximum amount of power required during a particular billing period. This is known as a demand charge, or capacity charge, and is typically applied in dollars per kilowatt. (Electricity demand meters usually average the instantaneous power over periods of about fifteen minutes.)

Consumption charge

The consumer is also charged for the total amount of energy consumed. While power is the rate at which work is done, **energy consumption*** is a measure of the amount of work done. Using the car analogy, just as power is like the speed of a car, energy consumption can be compared to the distance travelled by the car. The consumption charge, or energy charge, is typically applied in cents per kilowatt-hour.

***Power** is the rate at which work is done and is measured in kilowatts (kW).

***Energy consumption** is a measure of the amount of work done and is measured in kilowatt-hours (kWh). The amount of energy consumed is the amount of the power times the amount of time for which the power is used.

1 kilowatt (kW) = 1000 Watts (W)

1 Watt = 1 Joule/second (J/s)

1 kilowatt-hour (kWh) = 1 kilowatt x 1 hour

1 kilowatt x 1 hour = 3.6 Megajoules (MJ)

Power factor adjustment

In addition to demand and consumption charges, commercial customers may be charged a very high penalty if their **power factor*** drops below a set amount, typically 90 per cent. The lower the power factor, the more power the utility has to generate, though no more demand may be registered on the demand meter. Electricity demand meters measure only the resistive power, the part that actually performs work; whereas the utility must deliver sufficient power to account for the total apparent power used by a customer. A special meter is required to measure the total apparent power, which is measured in kilovolt-amps.

The power factor penalty is typically applied by adjusting the demand charge to be based on a percentage of the peak kilovolt-amp reading, instead of on the peak demand. For example, if a utility charges a penalty for a power factor below 90 per cent, the power factor adjustment would be made by calculating the demand charge using 90 per cent of the peak kilovolt-amp reading, instead of using the peak demand reading.

***Power factor** is the amount of the portion of power that actually performs work, known as resistive power and measured in kilowatts (kW), divided by the total apparent power, measured in kilovolt-amps (kVA). The power factor may be expressed as a percentage or as a number between 0 and 1.

$$\text{Power Factor} = \frac{\text{Resistive Power (kW)}}{\text{Total Apparent Power (kVA)}}$$

Other charges

In addition to the consumption, demand and power factor charges, a customer may be billed for other items such as equipment rentals, transformer charges or metering charges. As well, there is usually some minimum fee to cover administration costs and the costs of providing a distribution system year round, even though the customer may only use electricity for part of the year. Electricity is also subject to the Goods and Services Tax.

Rate structures

Sometimes the rate structure may be as simple as having a single rate for demand and one for consumption. This is known as a flat-rate structure. A more typical rate structure though is the declining block form in which the electricity demand and consumption in a billing period are broken down into blocks, with the lower blocks being charged at higher rates. Examples of a declining rate structure and an electricity bill are given below.

How to reduce your electricity bill

After understanding the different electricity charges, one realizes that there are several means of reducing one's electricity bill, aside from reducing consumption, without reducing the services provided.

1. Avoid power factor penalties

Avoid power factor penalties whenever possible. Whenever power is supplied to an inductive load (such as an electric motor, a transformer, or a fluorescent light) power factor is reduced. Capacitors may be installed to increase the power factor.

2. Reduce demand charges

Depending on the type of electric equipment in the building, demand charges may be reduced by load shifting. Load shifting is a method of reducing peak demands by moving some of the electricity demand ahead or delaying it until after the normal peak.

3. Apply for a different rate structures

Some utilities offer a variety of different rate structures for commercial customers. "Time-of-Use" rate may be suitable for facilities where much of the electricity is consumed during off-peak hours, since off-peak electricity is charged at a lower rate. Some utilities also offer an interruptible service in which customers receive electricity at lower rates in return for allowing the utility to temporarily reduce or stop electricity delivery to their facility when the utility as a whole is experiencing peak power demands.

Example of a declining block structure for electricity rates

Demand charge:	first 50 kW — no charge next 4,950 kW — $5.15 /kW remaining kW — $13.50 /kW
Consumption charge:	first 250 kWh — $0.085/kWh next 15,250 kWh — $0.08/kWh next 1,984,500 kWh — $0.06/kWh remaining kWh — $0.045/kWh
Minimum monthly charge:	if under 50 kW — $5.00 if over 50 kW — $0.60/kW (based on the maximum demand during the previous 11 months)

Example of an electricity bill with declining block rates

During a billing period, 60,000 kWh of electricity was consumed with a peak demand of 100 kW. The declining rate structure given above applies.

	Totals
Demand charges:	
first 50 kW are free = $ 0.00	
remaining 50 kW @ $5.15/kW = $257.50	$ 257.50
Consumption charges:	
first 250 kWh @ $0.085/kWh = $21.25	
next 15,250 kWh @ $0.08/kWh = $1,220.00	
remaining 44,500 kWh @ $0.060/kWh = $2,670.00	$3,911.25
SUBTOTAL	**$4,168.75**
Plus 7% GST	$ 291.81
TOTAL BILL	**$4,460.56**

Note: Even if no electricity had been consumed this billing period, a minimum charge of $60 ($.60 / KW x 100 KW) plus GST would still have been charged, assuming that the maximum demand in the previous 11 months had been 100 KW.

Gas Utility Rates

Gas rates are structured like the declining block rates often used for electricity. A customer's gas consumption is broken down into blocks, with the lower blocks being charged higher rates per unit of gas. Typically gas charges are applied in dollars per cubic meter ($/m^3$) or dollars per gigajoule (GJ), where a gigajoule is the measure of the energy content of the fuel delivered. Examples of gas rates and a gas bill are shown below. The key to reducing your gas bill is to reduce your gas consumption.

1 gigajoule (GJ) = 10^9 joules

Example of gas rates

Consumption charge:	first 6.0 GJ — $5.571 /GJ
	next 99.5 GJ — $4.891/GJ
	remaining GJ — $4.273/GJ

Minimum monthly charges: $15.00 monthly minimum plus GST

Example of a gas bill

During a billing period, a customer consumed 400 GJ of gas. The gas rates given above apply.

	Totals
Consumption charges:	
first 6.0 GJ @ $5.571/GJ = $33.43	
next 99.5 GJ @ $4.891/GJ = $486.65	
remaining 294.5 GJ @ $4.273/GJ = $1258.40	
SUBTOTAL	**$1,778.48**
Plus 7% GST	$ 124.49
TOTAL BILL	**$1,902.97**

Steam, Oil, Diesel, Water and Other Utility Rates

The utility rates for other fuels and resources, such as steam, oil, diesel or water, are typically charged on the basis of bulk billing units, as shown in Table 1. Not all of these are metered. While steam or water is metered regularly for billing purposes, oil and diesel tanks are usually filled seasonally or at irregular intervals. When a fuel or resource is not regularly metered by the utility, manual maintenance of log books may be required for energy tracking purposes.

Table 1 - Typical billing units for other fuels and resources

	SI Units	Imperial Units
Steam	$/1000 kg	$/1000 pounds
Oil	$/cubic meter	$/gallon
Diesel	$/cubic meter	$/gallon
Water	$/cubic meter	$/gallon

Energy Tracking Using Utility Billing Data

Utility billing data may be used effectively to track energy use and monitor building energy performance. This may be done manually or through the use of computer software. In either case, utility usage must be recorded and properly analysed. Analysis must account for billing period variations, as well as variations in weather. It must also be realized that building energy performance will vary, not only due to building system upgrades, but to other changes in the building, such as variations in floor space, equipment loads and schedules, and occupancy loads and schedules.

Many computer packages are available to account for the above variations, while automatically checking for "reasonable" data and verifying utility bill calculations. As well, most software programs include a comprehensive choice of analysis tools including histories, averaging, trend analysis, comparisons, graphing and other reporting capabilities.

For further information please contact:

Industrial, Commercial and Institutional Programs, Natural Resources Canada
580 Booth Street, 18th Floor, Ottawa, Ontario K1A 0E4, Fax: (613) 947-4121

References

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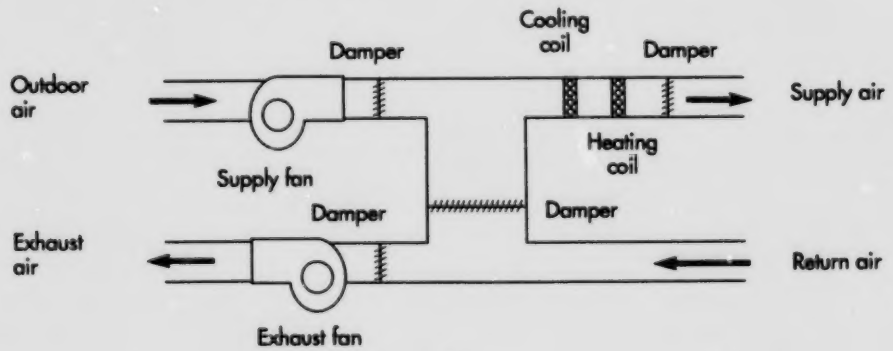
ENERGY EFFICIENCY

VENTILATION SYSTEMS

The purpose of a building's ventilation system is to ensure good indoor air quality and to distribute heat or cold around the building. While a ventilation system can consume a large quantity of energy, it is possible to make the indoor environment a more comfortable and productive work place and to save energy and money at the same time — sometimes by making only minor adjustments or by following simple maintenance procedures to the system. The process of tuning up a building's ventilation system is sometimes referred to as "recommissioning" the system. This fact sheet provides an overview of how a ventilation system works and some tips for reducing the energy it consumes.

It is important to note that there are three main types of ventilation air: *outdoor air*, *return air* and *supply air*. In office buildings, fresh outdoor air is brought into the building by large fans. Return air is air that has already been delivered to the building. Some return air is exhausted out of the building by another set of large fans or is mixed with outdoor air to produce supply air. The supply air is heated or cooled as necessary and delivered to the building. Fans and dampers control the mixing and distribution of the three types of ventilation air, while filters are used to clean the air.

Figure 1 - Fans and dampers control the distribution of outdoor, return and supply air



It is very important that sufficient fresh air be brought into the building to ensure a healthy and productive work environment. Many building codes in Canada refer to the American Society of Heating Refrigeration and Air-conditioning Engineer's ventilation standard, ASHRAE 69-1989, to define outdoor air requirements. This standard requires at least 10 litres per second per person of outdoor air to be delivered in a normal office. In areas where more air contaminants are generated, higher ventilation rates may be required and a local ventilation system is recommended.

Energy Saving Tips

There are many ways to save energy in the ventilation systems of a building. These range from the little to no-cost changes, like simply operating a system differently or doing some minor maintenance, to more complicated retrofits, such as upgrading pieces of equipment or redesigning a whole system. In either case, the results may be very cost effective and may provide the occupants with a more comfortable working environment. The following is a list of just a few energy saving tips for the ventilation system.

1. Conduct Regular Maintenance

Just like an automobile needs tuning, ventilation equipment requires regular maintenance procedures to keep it operating as efficiently as possible.

- Filters should be changed and cleaned regularly. Not only will this improve air quality, but it will improve the efficiency of the fans which have to pull or push air through the filters.
- The dampers, which control the amount of outdoor air brought in and the mixing of the return and outdoor air, should be checked to ensure correct operation.
- Belt drives on the equipment should be adjusted and replaced as required.
- Air ducts should be insulated and repaired as required in order to reduce distribution losses; it's not uncommon for as much as 10 to 20 per cent of the air moving through a duct to never make it to the designated outlet.

2. Adjust the Controls

Even without changing the ventilation equipment, energy savings can often be achieved by simply adjusting the control systems.

- During a building's unoccupied hours, ventilation rates can be reduced. Fans can be put on timers or on an energy management control system to control their hours of operation. However, when setting timers, make sure to allow sufficient time for fans to ventilate the building prior to its normal hours of occupation.

3. Upgrade Equipment

Energy savings can be achieved by making minor changes to equipment. When replacing equipment, consider high efficiency alternatives wherever possible.

- Use variable speed drives whenever possible. (Refer to the fact sheet called "Adjustable Speed Drives".)
- Use ceiling fans where there are very high ceilings.

4. Modify the Systems

Although more involved, modifying the systems can often result in substantial energy savings.

- The addition of heat recovery equipment to the ventilation system is becoming more cost- effective, as energy costs and the demand for higher ventilation rates increase. Heat recovery equipment, also known as energy recovery equipment, can save energy by using the heat or cold from the exhaust air to pretreat the incoming air, thereby

reducing the heating or cooling loads on the HVAC equipment. An air-to-air heat exchanger is used to transfer the heat from one air stream to another.

- With the advent of computer technology, energy management control systems are becoming more economical. (Refer to the fact sheet called "Energy Management and Control Systems".)

Conclusions

The ventilation system of a building can be adjusted and maintained to provide a comfortable and healthy work environment in an energy-efficient manner. Building operators, property managers and tenants should all work together to improve the operation of ventilation systems. Building operators should receive regular training on new technologies and maintenance procedures; tenants should provide constructive feedback to the building maintenance staff; and property managers should stay informed of the issues so that they can make practical decisions regarding system upgrades.

For further information please contact:

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580 Booth Street, 18th Floor, Ottawa, Ontario K1A 0E4, Fax: (613) 947-4121

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ENERGY EFFICIENCY

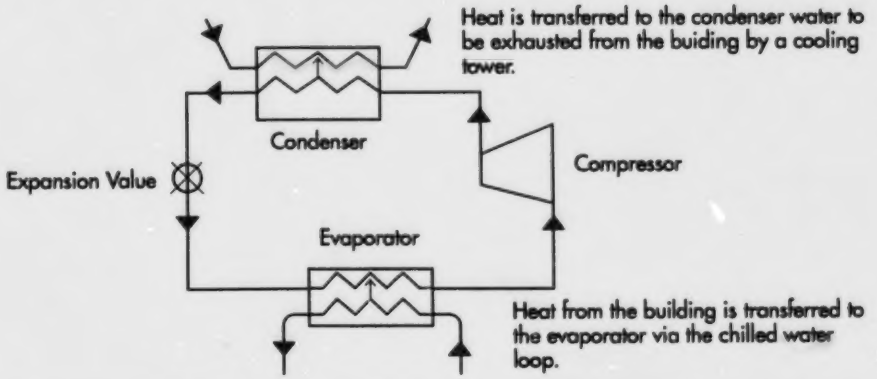
COOLING SYSTEMS

A cooling system must continually adjust the amount of heat removed from a building in response to ever-changing heat gains and losses. (Refer to the "Heating, Ventilation and Air-conditioning" fact sheet for more details on heat gains and losses in a building.) A cooling system can consume a large amount of energy in an office building. However, often with only minor adjustments or simple maintenance procedures made to the cooling system, it is possible to not only make the indoor environment a more comfortable and productive work place, but at the same time save energy and money. This process of tuning-up a building's cooling system is sometimes referred to as "recommissioning" the system. This fact sheet provides an overview of the cooling equipment that may be found in an office building and some of the methods for reducing the energy consumed by the system.

Cooling Equipment

The following equipment may be used to remove unwanted heat from a building: chillers, air conditioners, cooling towers, evaporative coolers or heat pumps. For information on heat pumps refer to the fact sheet on "Heating Systems".

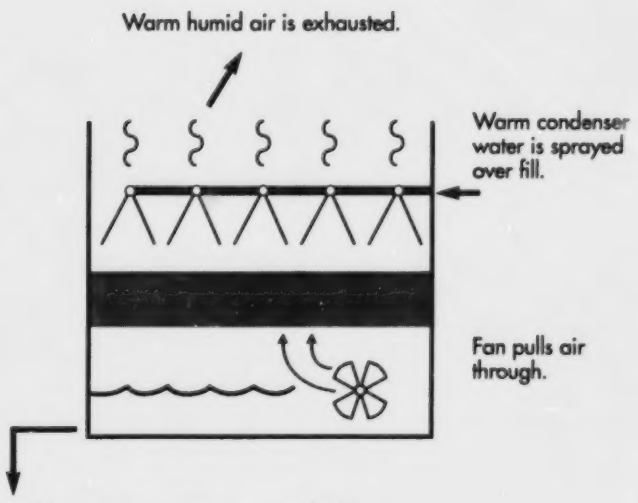
Figure 1 - Cooling equipment that operates on a vapour compression cycle consists of a refrigerant loop with an evaporator, a compressor, a condenser, and an expansion valve


Heat is transferred to the condenser water to be exhausted from the buiding by a cooling tower.
Condenser
Compressor
Expansion Value
Evaporator
Heat from the building is transferred to the evaporator via the chilled water loop.

Chillers, air conditioners, roof top units

Cooling equipment, such as air conditioners, roof top units, and some types of chillers, works on what is known by mechanical engineers as a "vapour compression cycle". For these types of equipment, a refrigerant flows around a loop with an evaporator, a compressor, a condenser and an expansion valve. Basically, evaporators and condensers are heat exchangers which transfer heat from one fluid to another. In an evaporator, the refrigerant gains heat from the building and changes from a liquid to a gas. The compressor then pumps the refrigerant to a higher temperature and pressure. The compressor may be electrically powered or driven by a gas-fired engine. In the condenser, heat is released from the refrigerant and the refrigerant condenses back into liquid form. The refrigerant then passes through an expansion valve where its pressure is reduced and the cycle begins again.

Figure 2 - A cooling tower exhausts the heat from the building


Warm humid air is exhausted.
Warm condenser water is sprayed over fill.
Fan pulls air through.
Cold condenser water returns to building.

Some types of chillers replace the compressor in the loop with an absorber and a generator. These are known as absorption chillers and they contain a secondary fluid, or absorbent, usually lithium bromide or ammonia, with water as the refrigerant. Absorption chillers use heat as the driving force for generating the cooling. Absorption chillers can be very cost effective when waste heat from the building's electric generating system is used to power the chiller. This combined system is known as a cogeneration system. (Refer to the fact sheet on "Cogeneration technology".)

Cooling Towers

Cooling towers are located on the exterior of a building, usually on the roof, where the outdoor air helps the heat from the building to dissipate through evaporation. As we all have experienced when stepping out of an outdoor swimming pool, especially on a windy day, evaporating water provides cooling. Cooling towers use this same principle by creating a film or spray with the water to be cooled, and then use either a fan or natural wind currents to evaporate the water. The water then condenses and this cooler water is returned to the building. Cooling towers may be used to dissipate heat from the condenser of cooling equipment or may be run directly to dissipate heat from a chilled water loop.

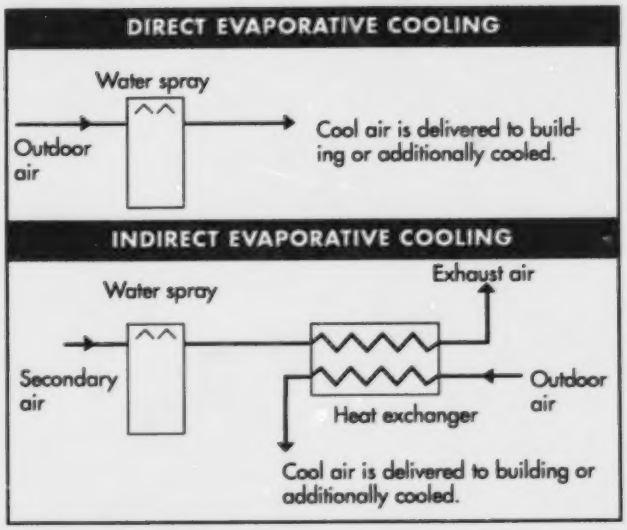
Evaporative Coolers

Evaporative coolers also use evaporation to provide cooling, but this time it's the ventilation air that is cooled. With direct evaporative cooling, water is sprayed into the incoming outdoor air and as the water evaporates it cools the air. This cool air may be delivered to the building or additionally cooled by other means. With indirect evaporative cooling, a secondary air stream is cooled by direct evaporative cooling and this secondary air stream is used to cool the incoming outdoor air through an air-to-air heat exchanger. Either room exhaust air or

outdoor air may be used as the secondary air stream. When exhaust air is used as the secondary air stream, indirect evaporative cooling systems can be used to pre-treat the incoming air even without the exhaust air being evaporatively cooled. As such, these systems can also double as heat recovery systems in winter.

Both the humidity and the temperature of the outdoor air are important factors in assessing whether evaporative cooling is economical for a particular climate. With direct evaporative cooling, the outdoor air must be very dry, since its humidity is increased with the evaporation process. The energy savings provided by the evaporative cooling system must be compared to the additional energy required by water pumps and fans.

Figure 3 - Direct or evaporative cooling may be used to cool or precool air



Energy Saving Tips

There are many ways to save energy with the cooling system of a building. These range from the little- to no-cost changes, such as operating a system differently or doing some minor maintenance, to more complicated retrofits, such as upgrading pieces of equipment or re-designing the system. In either case, the results may be very cost effective and may provide the occupants with a more comfortable working environment. The following is a list of just a few energy saving tips for the cooling system:

1. Conduct regular maintenance

Just like an automobile needs regular maintenance, there are many maintenance procedures that should be conducted regularly on cooling equipment to keep it operating as efficiently as possible.

- Cooling coils should be cleaned regularly, removing any lint and dust build up, as should fans and their inlet screens.
- Dampers, which control the amount of outdoor air brought in and the mixing of return and outdoor air, should be checked to ensure that they are operating correctly.
- Belt drives on the equipment should be adjusted and replaced as required.
- Pipes and ducts should be insulated and repaired as required in order to reduce distribution losses — it's not uncommon to lose as much as 10 to 20 per cent of the air moving through a duct prior to its reaching its destination.

2. Adjust the controls

Even without changing the cooling equipment, energy savings can often be achieved by simply adjusting the control systems.

- Supply air and water temperatures should be adjusted so that fluid is not overcooled.
- During the cooling season, air and water temperatures should be allowed to increase when the building is unoccupied. Be sure to avoid peak demands for electricity when returning to the building's normal temperatures.
- The chilled water temperature and the condenser water temperature should be

optimized. Often energy savings can be achieved by raising the chilled water temperature and lowering the condenser water temperature; but, this requires careful examination of the whole system.

- Free-cooling should be used wherever possible; when the outdoor air is cool enough, use it as a cooling source. Free cooling can be done simply by pulling in outdoor air to be mixed with the return air to achieve the appropriate supply air temperature. This is known as an economizer cycle. Another way of using free cooling is to use outdoor air for evaporative cooling, as described in the cooling equipment section.

3. Upgrade equipment

Energy savings can also be achieved by making minor changes to equipment. When replacing equipment, consider high efficiency equipment wherever possible.

- Use variable speed drives whenever possible. (Refer to the fact sheet called "Adjustable Speed Drives".)
- Use ceiling fans where there are very high ceilings.

4. Modify the Systems

Although more involved, modifying the systems can often result in substantial energy savings.

- The addition of heat recovery equipment to the ventilation system is becoming more cost effective, as energy costs and the demand for higher ventilation rates increase. Heat recovery equipment, better referred to as energy recovery equipment, can save energy by pre-cooling incoming air with exhaust air. Heat recovery equipment will also save energy in the heating season by warming up incoming air with exhaust air.
- With the advent of computer technology, energy management control systems are becoming more economical. (Refer to the fact sheet called "Energy Management and Control Systems".)
- As described in the cooling equipment section, sometimes a cooling tower alone can provide sufficient cooling without the use of chillers. In order to do this, however, some changes may have to be made in the plumbing so that heat can be transferred directly from the chilled water to the cooling tower, through a heat exchanger.
- Usually chillers operate much more efficiently at full load, than at part load. Hence, it is preferable to have multiple chillers rather than one large unit.

Conclusions

The cooling system of a building can be adjusted and maintained to provide a comfortable and healthy work environment in an energy-efficient manner. Building operators, property managers and tenants should all work together to improve the operation of the cooling system. Building operators should receive regular training on new technologies and maintenance procedures; tenants should provide constructive feedback to building maintenance staff; and property managers should stay informed of the issues so that they can make practical decisions regarding system upgrades.

For further information please contact:

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ENERGY EFFICIENCY

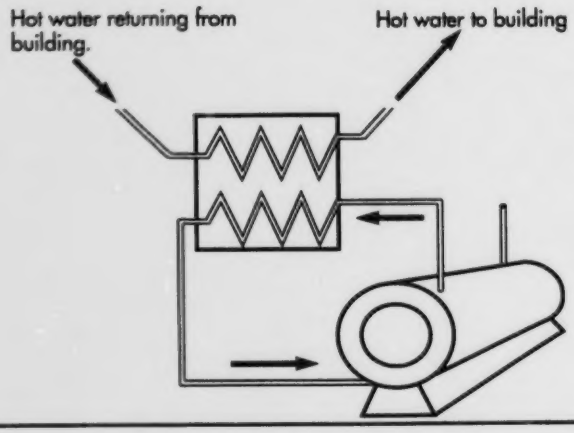
HEATING SYSTEMS

A heating system must continually adjust the amount of heat being delivered to a building in response to ever-changing heat gains and losses. (Refer to the "Heating, Ventilation and Air-conditioning" fact sheet for more details on heat gains and losses in a building.) The heating system can consume a large amount of energy in an office building. With only minor adjustments or simple maintenance procedures, it is often possible to not only make the indoor environment a more comfortable and productive work place, but to also save energy and money. The process of tuning-up a building's heating system is sometimes referred to as "recommissioning" the system.

This fact sheet provides an overview on the heating equipment that may be found in an office building and some of the methods for reducing the amount of energy consumed by the system.

Heat is delivered to a space in a building through a heat transfer medium, typically air and/or water. The amount of heat transferred is adjusted by varying the temperature

Figure 1- A boiler may burn fuel, such as oil or gas, to heat water which is then used to heat the water that is delivered to the building



and/or the amount of water or air being delivered to the space. This is done by adjusting the equipment that generates the heat and/or the equipment that distributes the heat. When water is used to distribute heat, valves and pumps control the flow of the fluid along pipes. Heat may be delivered directly to the space through a radiation system, such as perimeter hot water radiation, or it may be used to warm up the air being delivered to the space. In the latter case, heat exchangers transfer energy from the water to the air.

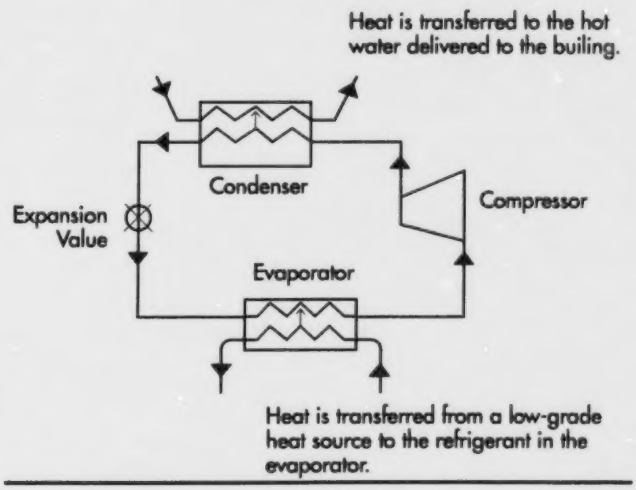
Heating Equipment

In a typical office building, boilers, electric heating coils, or heat pumps are used to generate the heat.

Boilers

Boilers burn a fuel, such as oil or gas, or use electric resistance coils to generate heat. The energy is transferred to either hot water or steam. The hot water or steam is then used to heat the air or water being delivered to the building with heat transfer equipment, such as water-to-air or water-to-water heat exchangers. A building may rely upon only one boiler (although typically there is at least one other for back up) or several which operate in series or in parallel. Sometimes many boilers are contained in one building to provide hot water or steam to several buildings and this is known as a central heating plant.

Figure 2 - A heat pump consists of a refrigerant loop with an evaporator, a compressor, an expansion valve and a condenser.


Heat is transferred to the hot water delivered to the buiiing.
Condenser
Compressor
Expansion Value
Evaporator
Heat is transferred from a low-grade heat source to the refrigerant in the evaporator.

Electric heating coils

Electric heating coils, such as baseboard heating or electric resistance coils within a ventilation system, are often used in office buildings due to their low initial cost, ease of installation and ease of individual metering and billing. Although electric heating coils are 100 per cent efficient at the user's end, energy is lost at the electricity generating station and in the distribution system — and the user is charged for this lost energy. As a result, this form of heating is typically very expensive and other forms of heating would be much more cost effective, except where fuels are relatively very expensive.

Heat pumps

Heat pumps typically use electricity to upgrade energy from a source, such as the ground or waste heat from industrial processes, to a temperature useful for heating a building. Heat pumps operate in the same manner as a refrigerator which uses electricity to pump heat from a cooler temperature to a warmer temperature — which is in the opposite direction from the way that heat would normally travel. Heat pumps are often reversible; that is, they can be used to pump heat into a building and then operated in reverse during the cooling season to pump heat out of the building.

A heat pump consists of a refrigerant which flows around a loop with an evaporator, a compressor, an expansion valve and a condenser. Basically, evaporators and condensers are heat exchangers which transfer heat from one fluid to another. In an evaporator, the refrigerant gains heat as it evaporates and becomes a gas. In a

compressor, electricity is typically used to mechanically pump the refrigerant to a higher temperature (and pressure), so that the heat will be given off in the condenser. As heat is released in the condenser, the refrigerant reduces in temperature and condenses back into a liquid form. Then the refrigerant passes through an expansion valve which reduces the pressure and the cycle begins again.

As with boilers, heat pumps transfer the heat to either air or water, which is then distributed around the building. Heat pumps may be located and operated individually throughout the building or they may be connected to a common water loop in series with other main sources of heating and of cooling. This latter configuration is known as a water-loop heat pump system and can be very efficient in buildings where some parts of the building may require cooling (such as the interior of the building or the south side) while other parts (such as the perimeter or the north side) require heating. (Refer to the "Water-loop Heat Pump" fact sheet for more details on this type of system.)

Energy Saving Tips

There are many ways to save energy in the heating systems of a building. These range from little- to no-cost changes, such as operating the system differently or doing some minor maintenance, to more complicated retrofits, such as upgrading pieces of equipment or re-designing a whole system. In either case, the results may be very cost effective and may provide the occupants with a more comfortable working environment. The following is a list of just a few energy saving tips for heating systems:

1. Conduct regular maintenance

Just like an automobile needs regular maintenance, there are many maintenance procedures that should be conducted regularly on heating equipment to keep it operating as efficiently as possible.

- Heating coils should be cleaned regularly, removing any lint and dust build up.
- Dampers, which control the amount of outdoor air brought in and the mixing of the return and outdoor air, should be checked to ensure that they are operating correctly.
- Belt drives on equipment should be adjusted and replaced as required.
- Pipes and ducts should be insulated and repaired as required, in order to reduce distribution losses — it's not uncommon to lose as much as 10 to 20 per cent of the air moving through a duct on the way to its destination.

2. Adjust the controls

Even without changing the heating equipment, energy savings can often be achieved by simply adjusting the control systems.

- The supply air and water temperatures should be adjusted to reduce the likelihood of overheating the fluid.
- Air and water temperatures should also be reduced during the building's unoccupied periods. Be sure to avoid peak demands for electricity when returning to the building's normal temperatures.

3. Upgrade equipment

Energy savings can be achieved by making minor changes to equipment. When replacing equipment, consider high efficiency equipment wherever possible.

- Use variable speed drives on pumps and fans wherever possible. (Refer to the fact sheet called "Adjustable Speed Drives".)
- Use ceiling fans where there are very high ceilings.

4. Modify the Systems

Although more involved, modifying the systems can often result in substantial energy savings.

- The addition of heat recovery equipment to the ventilation system is becoming more cost effective, as energy costs and the demand for higher ventilation rates increase. Heat recovery equipment can save energy by using heat from exhaust air to pre-treat incoming air, thereby reducing heating load. Heat recovery equipment will also save energy in the cooling season, by precooling incoming air with exhaust air.
- With the advent of computer technology, energy management control systems are becoming more economical. (Refer to the fact sheet called "Energy Management and Control Systems".)
- Usually boilers operate much more efficiently at full load, rather than at part load. Hence, it is preferable to have multiple boilers rather than one large one. As well, in some buildings the domestic hot water (DHW) is heated by the building's main boiler(s). Although this may be quite efficient during the heating season, it may mean that at other times of the year a large boiler has to be operated continuously and only at part-load. In this case it is probably more efficient to have a separate boiler for the DHW system so that the large boiler does not have to be operated during the cooling season.

Conclusions

The heating system of a building can be adjusted and maintained to provide a comfortable and healthy work environment in an energy-efficient manner. Building operators, property managers and tenants should all work together to improve the operation of the heating system. Building operators should receive regular training on new technologies and maintenance procedures; tenants should provide constructive feedback to building maintenance staff; and property managers should stay informed of the issues so that they can make practical decisions regarding upgrades to the systems.

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ENERGY EFFICIENCY

HEATING, VENTILATION, AND AIR-CONDITIONING SYSTEMS

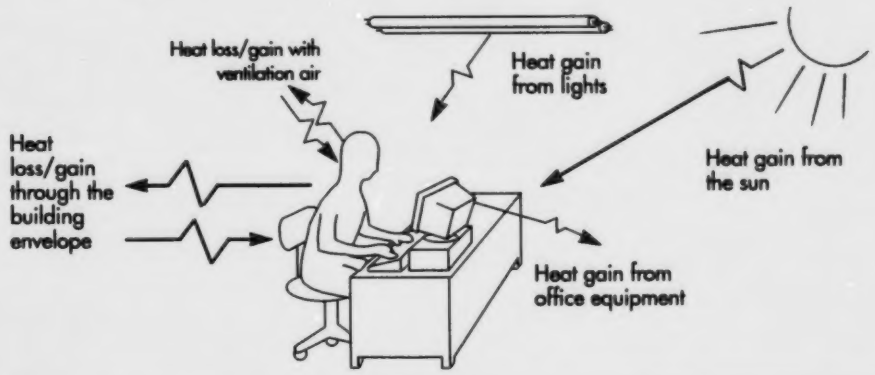
The heating, ventilation and air-conditioning (HVAC) systems of a building consist of many inter-related electrical and mechanical pieces of equipment working together to control the temperature, humidity, and ventilation in the building. In Canada, HVAC systems generally consume about 60 per cent of the energy consumed by an office building. With only minor adjustments or simple maintenance procedures to the HVAC systems, it is possible to make the indoor environment a more comfortable and productive work place and also save energy and money. The process of tuning up a building's HVAC systems is sometimes referred to as "recommissioning" the building.

In order to understand how this can be done, one must first understand how the heating, cooling and ventilation systems in a building work. This fact sheet provides an overview of how heat and moisture are lost and gained in a building; how the heating, cooling and ventilation equipment work; and some general methods for reducing the energy consumed by the HVAC systems.

Heat Gains and Losses in a Building

To control the temperature in a building, the heating and cooling systems must respond to the various heat gains and losses in a building, as shown in Figure 1.

Figure 1 - The heat gains and losses in a building


Heat loss/gain with ventilation air
Heat gain from lights
Heat loss/gain through the building envelope
Heat gain from the sun
Heat gain from office equipment

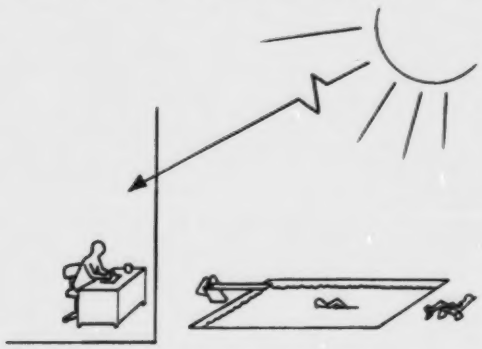
External heat gains and losses

One of the main heat losses or gains in a building is due to ventilation air. Ventilation air is required to maintain good indoor air quality within a building. Fans pull in fresh air from the outside while exhausting stale air. Generally this fresh air must either be heated or cooled, depending upon the season.

Aside from the controlled ventilation air, heat is also lost or gained from the air that leaks through the building envelope. During the heating season, heat flows out of a building, thereby increasing the HVAC system's heating load; while during the cooling season, heat flows into a building, increasing the cooling load. The greater the thermal resistance, or the more insulation in the walls and roof, the less heat is conducted through the building envelope. A good air barrier is also important to reduce the heat lost or gained with air leakage.

Another large source of heat whose influence upon the temperature in a building is often forgotten is the sun. Although more than 150,000,000 kilometres from the earth, the sun can cause as much as 650 watt-hours of heat gain in a building for every square metre of glass in one hour. The exact amount of solar heat gain depends upon a number of factors, such as the type of glass, the amount of internal and external shading on the window, the window orientation, the location of the building, and the time of day and year. In fact, during the winter in Canada, the solar heat gains in a building can be very large since the sun is lower in the sky and its rays are more able to penetrate vertical faces of glass.

Figure 2 — 650 kWh can raise the temperature of swimming pool 10°C



Example

The south-facing wall of a Toronto office building has windows made of standard double pane glass. From 13:00 to 14:00 on a clear sunny day, in the middle of February, 650 watt-hours of solar energy are radiated into the building for every square metre of glass on the south. In other words, if the building had 1,000 square metres of windows on the south side, 650 kilowatt-hours of heat would be gained. This is enough energy to heat a 10 metre swimming pool, with 55,900 litres of water, from a chilly 10°C to a comfortable 20°C. Imagine how much havoc this effect could wreak on HVAC systems which are trying to maintain a constant temperature in the building.

Internal heat gains

Not only does the external environment affect the heat balance, but internal heat sources are also present in a building. In fact, office buildings have such large internal heat gains that cooling is often required for the core of the building, even during the "heating" season. People are like little furnaces, each giving off about 115 watt-hours of heat every hour while doing light office work.

Office equipment is another major source of heat. Computers, printers, photocopiers and facsimile machines all produce heat. A personal computer may produce between 90 and 530 watt-hours of heat every hour, a laser printer between 180 and 870 watt-hours and photocopiers between 2,200 and 6,600 watt-hours.

Lighting is another internal heat source. Nearly 90 per cent of the energy consumed by an incandescent light is converted directly to heat, while even energy-efficient compact fluorescent lamps convert about 30 per cent of the energy that they consume directly to heat .

Moisture Gains and Losses in a Building

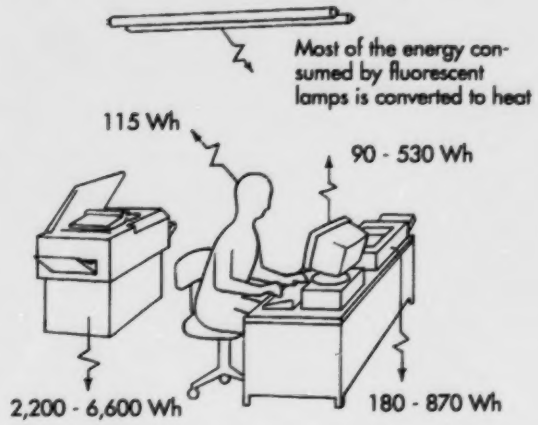
The causes for moisture gains and losses in a building are much the same as for heat. The air brought into a building via the ventilation system or through air leakage not only affects heat gain or loss in the building, but also the level of humidity. During the heating season, cold air brought in is often very dry, since colder air cannot hold as much moisture. The air may require humidification to maintain a comfortable and healthy relative humidity — ideally between 40 and 60 per cent. During the cooling season, air brought into the building is often very humid and can make warm air temperatures feel even hotter. People and plants also contribute to the humidity level in a building.

Equipment

The HVAC system must continually adjust the amount of heat being delivered to or removed from the building in response to the ever changing heat sources and losses described above. The heat is delivered to, or removed from, a particular space in the building through a heat transfer medium, typically air and/or water. The amount of heat transferred is adjusted by varying the temperature and/or the amount of water or air being delivered to the space. This is done by adjusting the equipment that generates or dissipates the heat and/or the equipment that distributes the heat, such as fans, pumps, and valves.

In a typical office building, boilers, electric heating coils or heat pumps are used to generate heat; while chillers, air conditioners, cooling towers, evaporative coolers or heat pumps are used to remove unwanted heat.

Figure 3 - Internal heat gains in an office building



Heat is usually distributed around the building in either air or water. Air can be humidified by spraying water or steam into it. Cooling equipment can remove humidity from the air by reducing its temperature to the point where the water will condense and can then be drained off. Other devices may also be used to remove moisture from the air through the use of absorbent materials, also known as desiccants. Desiccants may be in a solid or liquid form. (The silica gel powder which comes in little packets with electronic equipment is an example of a desiccant.)

Whether air or water is used to deliver (or remove) heat to a space, a ventilation system is required to provide fresh air throughout the building in order to ensure good indoor air quality. Many building codes in Canada reference the American Society of Heating Refrigeration and Air-conditioning Engineers' ventilation standard, ASHRAE 69-1989, as the ventilation standard. This standard requires that at least 10 Litres of outdoor air per second per person be delivered in a normal office. In areas where more air contaminants are generated, higher ventilation rates may be required and a local ventilation system is recommended. Fans and dampers control the mixing and the distribution of the ventilation air in the air ducts and filters are used to clean the air.

When water is involved in the distribution of heat around a building, valves and pumps are used to control the flow of fluid along pipes. Heat or cold may be delivered directly to the space with water through a radiation system, such as perimeter hot water radiation, or it may be used to treat air being delivered to the space. In either case, heat exchangers may be used to transfer the energy from one fluid to another.

Energy Saving Tips

There are many cost effective ways to reduce the amount of energy used by the HVAC systems of a building and to provide the occupants with a more comfortable working environment. These range from little- to no-cost changes, such as operating a system differently or doing some minor maintenance, to more complicated retrofits such as upgrading equipment or redesigning a whole system. It is important to note that the best way to save energy with HVAC systems is to first reduce the need for them; that is, reduce all unnecessary heat gains and losses in a building.

- Improve the building envelope. In office buildings this can be done by improving the air barrier by sealing windows and wall joints or by replacing the windows with new window systems which have special coatings to reduce unwanted solar gains. For more information refer to the fact sheets on:
  - "The air barrier – one of the most critical elements in the buiding envelope" and
  - "Advanced windows"

- Replace the lighting with more energy efficient lighting systems. Many people might argue that reducing the heat gains from the lighting systems is ineffective since it will increase the heating costs. The fact is, although lights are not a very efficient way of heating a building; not to mention the fact that they rely on electricity which is typically much more expensive than the fuel used by the heating equipment. As well, reducing the summer cooling loads usually outweighs the increase in the winter heating loads since the cooling equipment is typically electrically powered and can cause the very expensive high peak demands for electricity. For more information, refer to the fact sheets on:
  - "Fluorescent lamps",
  - "Compact fluorescent lamps",
  - "Ballasts for fluorescent lamps",
  - "Occupancy sensors",
  - "High intensity discharge lamps",
  - "Exit signs",
  - "Fluorescent reflector fixtures" and
  - "Utility rates and billing practices".

- Replace the office equipment with more energy efficient equipment. The same arguments hold as for why it is worthwhile to have energy efficient lighting systems. Remember that office equipment is often left on throughout the whole day, even when it is not being used; that means that most office equipment will operate for fifty two weeks a year at nine hours every week day which works out to more than 2,300 hours a year. That means that reducing the power consumed by office equipment by one kilowatt may result in up to 2,300 kWh of electricity savings not to mention savings in electricity demand.

- Improve the HVAC systems. There are many ways to improve the HVAC systems in a building starting with simple maintenance procedures. For more information, refer to the fact sheets on:
  - "Heating systems",
  - "Ventilation systems",
  - "Cooling systems",
  - "Cogeneration technology",
  - "Thermal storage technology",
  - "Water loop heat pump",
  - "Energy management and control systems",
  - "Energy efficient motors" and
  - "Adjustable speed drives".

Conclusions

After implementing changes to a building, or whenever there are significant changes to the heat gains and losses in a building such as occupancy changes, it is important to note that the HVAC equipment should be adjusted accordingly. For example, the flow rates of the air and water being distributed around the building should be balanced and adjusted.

Although heating, ventilating and air conditioning systems are complicated, inter-related systems, they can be adjusted and maintained in such a manner as to provide a comfortable and healthy work environment in an energy-efficient manner. Building operators, property managers and tenants should all work together to improve the operation of the HVAC systems. Building operators should receive regular training on new HVAC technologies and maintenance procedures; tenants should provide constructive feedback to building maintenance staff; and property managers should stay informed of the issues so that they can make practical decisions regarding HVAC system upgrades.

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THERMAL STORAGE TECHNOLOGY

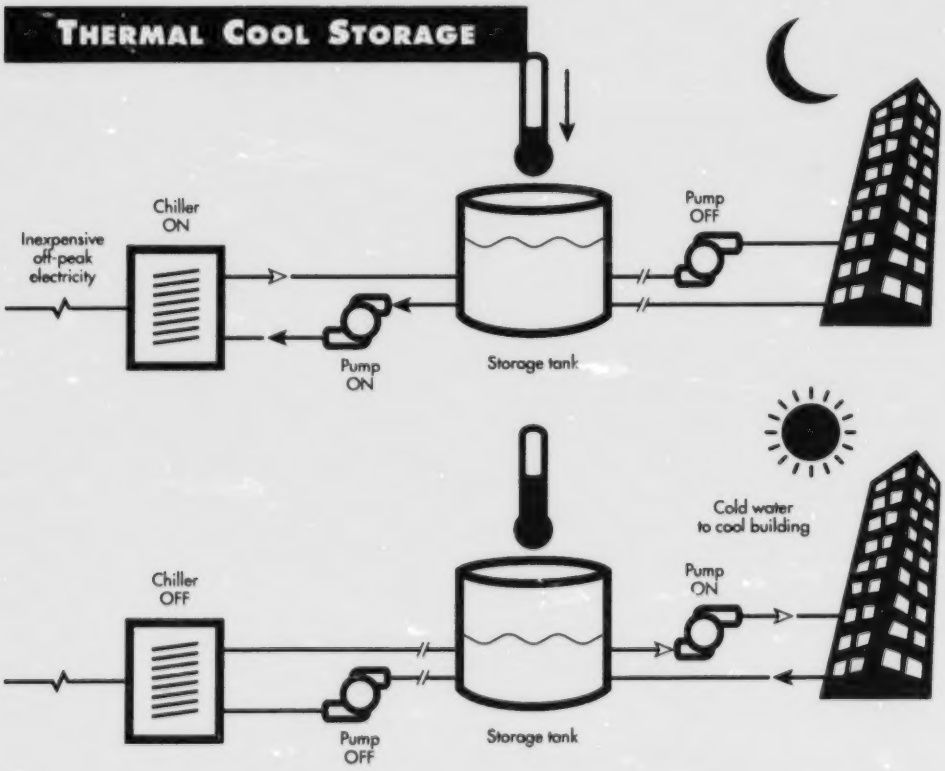
Air conditioning loads are the fastest growing sources of electrical usage in North America. The cooling equipment greatly increases the burden on the power distribution systems of all electrical utilities, and the peak loads caused by air-conditioning equipment naturally occurs during the daylight period. In order to deter the heavy loads placed on their systems, many utilities have implemented time-of-use rates, which have either lower or no demand charges and reduced energy charges during off-peak periods.

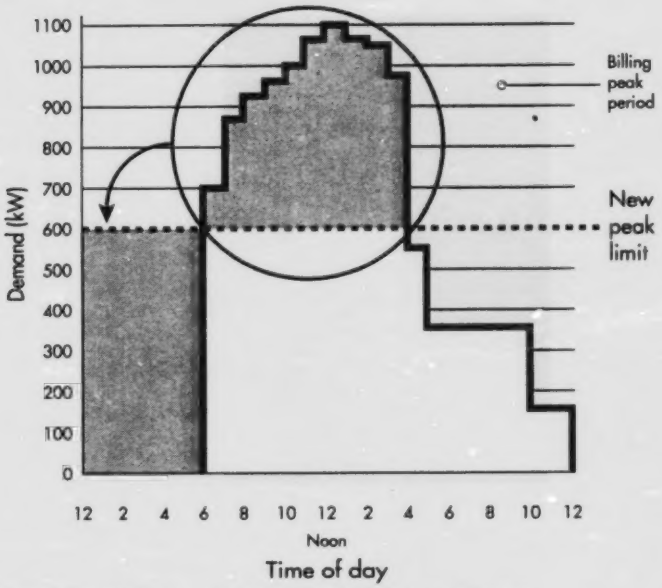
Thermal cool storage offers the only viable method of taking advantage of time-of-use rates by storing inexpensive off-peak (nighttime) electricity so it can be used for peak period cooling. By using stored thermal capacity to provide a cooling supplement during peak times of the day, electrical demand charges can be limited by the customer and a relatively flat electrical use profile may be achieved.

The Load Profile

The main key to understanding and applying Thermal Storage ideas to any facility is the Load Profile. The Load Profile is achieved by plotting cooling electric loads against time. In most federal buildings, the electricity consumption starts off low during the unoccupied early morning hours and builds to a maximum around midday. As the early evening approaches, the consumption declines back down (see Figure). The "hump" on the graph occurs during the utility's peak billing period and can be reduced by a number of different storage techniques. Each varies in the amount of peak demand that it displaces, which is a function of the energy amount that can be stored.

- ***Full Storage*** systems store the entire on-peak cooling requirement during off-peak hours. The capacity required for a full storage system is relatively large because sufficient thermal energy must be stored to supply the normal cooling load. These storage systems work well in retrofit applications as they can be designed to avoid the cost of additional chiller capacity.
- ***Partial Storage*** techniques involve storing enough thermal energy to displace only part of the facility's cooling load. The cooling load is satisfied using both the stored energy and existing cooling equipment. Partial storage is considered a good choice because it requires smaller chilling storage equipment than for full storage. The two most common techniques are Demand Limited and Load Levelling partial storage.
- *Demand Limited Partial Storage* is applicable for holding a facility's maximum electrical daytime demand to a predetermined level. Normally this level of peak demand is set by non-cooling loads.
- *Load Levelling Partial Storage* technique levels the cooling electrical demand when cooling over a specified "design day". It only supplies part of a facility's cooling load from storage. With this technique, the least amount of thermal storage capacity is used and is the least expensive to install.





Peak cooling demand is shifted to off-peak periods to take advantage of cheaper electricity rates

Thermal Cool Storage Technology – How it Works

Since it is very difficult and expensive to store electricity, the cheap off-peak electricity must be used to cool a substance which can then be stored until it is used for peak daytime use. Currently most building cooling is generated by a device called a chiller. A chiller is a packaged refrigeration device specifically designed to produce cold water or brine and has electric motors which consume a lot of electricity. Energy is saved by putting the chiller to work cooling water or making ice when rates are lower. Then, instead of having the chiller operate during the peak charge periods, it is turned off and the stored ice or water is circulated to cool the building.

- *Water Storage* – Currently, the best storage medium is water. Water is the most practical because of its low cost, high thermal storage capacity, non-toxicity, long life and ease of handling.
- *Ice Storage* – Ice storage systems are popular in retrofit applications where space may be limited, since they can store approximately 10 times more cooling energy per unit volume than chilled water. In many cases, a full storage ice system can easily be designed to meet the full cooling load requirements during the facility's peak hour.

Other storage materials are also available; but, toxicity, cost, heat storage capacity, and media degradation must be carefully examined.

Cold Air Distribution

A major benefit of implementing thermal cool storage is the ability to operate at lower water temperatures, which in turn produces lower supply air temperatures in the air handling systems. (Physically the cool liquid from the storage tanks is pumped to the air-handling duct area where it passes through many coils. Fans blow air which is cooled as it passes over the coils). Thermal storage produces supply air at 7°C instead of the usual 13°C. Cooler air is denser and occupies less volume. Since lower air volumes are required, fan energy is also reduced. A second benefit is greater dehumidification of the supply air. With lower humidity, the rooms can be kept slightly warmer than normal in summer while remaining comfortable.

The mechanical systems that distribute cold air at 7° C are less expensive than conventional systems because smaller capacity units are required. Practically all cost benefits result from space, structural and electrical cost savings. Specifically, these are floor-to-floor height reductions, less mechanical room space, small duct risers and smaller electrical wiring. For areas that need increased cooling loads, the use of cold air distribution handles more cool air without installing new duct work and/or fans. The use of cold air distribution technology allows many projects to become competitive on first cost when compared to non-storage air conditioning.

Thermal storage will increase operating flexibility for equipment with greater load capacity for shorter operating periods.

Example

A 26-storey office tower in downtown Ottawa was recently retrofitted with an ice-based thermal storage system. The 1.2 million square foot building had its peak load reduced by 479 kW. This resulted in over $44,000 in annual savings.

For further information please contact:
Industrial, Commercial and Institutional Programs, Natural Resources Canada,
580 Booth Street, 18th Floor, Ottawa, Ontario K1A 0E4, Fax: (613) 947-4121

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ENERGY EFFICIENCY

WATER LOOP HEAT PUMP

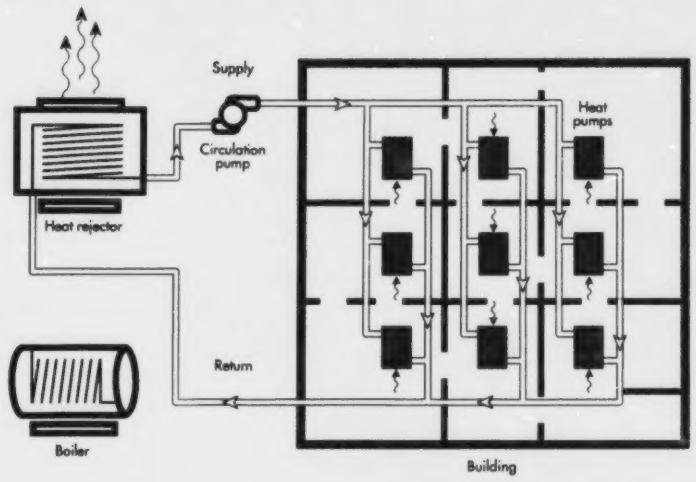
For heating and cooling, the water-loop heat pump (WLHP) system provides simplicity, efficiency and flexibility. Besides being able to heat or cool the building environment, a WLHP can save energy by transferring or balancing heat from building areas requiring cooling to areas requiring heating, at the same time.

Most office buildings are characterized by two distinct areas with considerably different load conditions – the core (interior) zone and the periphery (perimeter) zone. The core zone, at the centre of the building, is not affected by sun position or weather, except where there is exposed roof at the top floor. The peripheral zone (extending between 3.7 to 4.6m inward from the exterior wall around the building perimeter) experiences wide variations in space conditions due to changing sun position, weather, internal heat gains (heat generated by office equipment, lights and people) and heat losses.

During seasonal transitions from spring to summer and autumn to winter, one side of the building may require cooling due to solar heat gains, while heating is required at another due to low outside temperature. In winter, heating is required in peripheral areas to offset heat losses through the building envelope. This is particularly critical at night when there are virtually no internal heat gains (light, people, equipment), no external heat gains (solar), and outside temperatures are lower. Core cooling is often required year-round during occupied hours to offset the constant and fairly uniform heat gain.

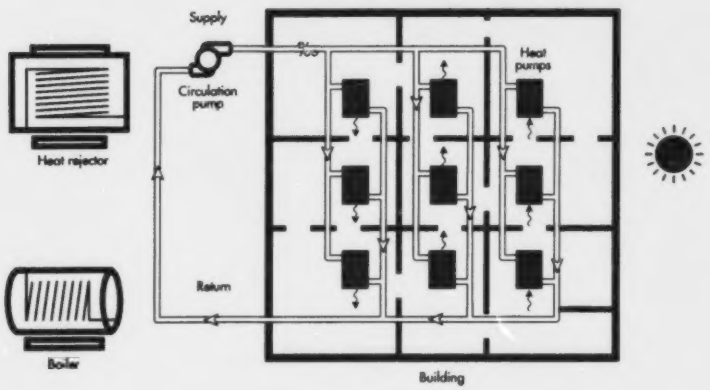
A conventional air-conditioning system requires operation of independent sources for heating and cooling throughout the year. Thus, heat-and cold-producing systems are at odds, wasting an unknown amount of energy annually. WLHP systems combat this wasteful simultaneous heating and cooling by optimizing the transfer of heat within the building.

Summer



The heat absorbed from the room air is transferred to the water loop. The heat rejector expels this heat outdoor.

Intermediate Seasons



Heat rejected to the loop on the sunny side of the building can be used for heating on the other side of the building.

Water Loop Heat Pump Technology - How it Works

A heat pump is a device that can both heat and cool by using a reversible refrigeration cycle. The water source heat pump can absorb heat from circulating water and transfer it to an air stream that is used for space heating purposes. When reversed, it can cool an air stream used for cooling and transfer the absorbed heat energy into circulating water.

Physically a year-round heating and cooling system consists of a series of individual water source heat pumps connected by a pipe loop network. The water circulating in the pipe loop is maintained between approximately 15°C and 35°C. During the winter months, when additional heat is required, a loop heater (a gas-fired boiler or electric element heaters) will "kick in" to add heat to the water loop. Likewise during the summer (or when there is excessive internal heat gain), the unwanted additional heat in the water loop is dissipated into the atmosphere through a cooling tower (also known as a heat rejector).

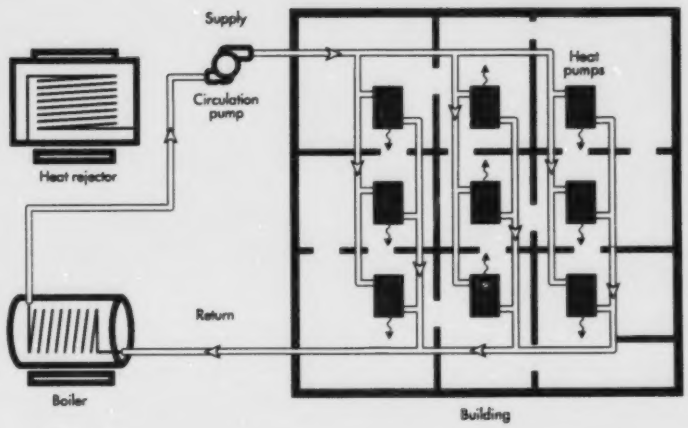
The water in the pipe loop serves as both a heat sink (absorbs heat) and a heat source (gives off heat). An individual heat pump can absorb heat from the loop or reject heat back into the loop at any time. The occupants may select heating or cooling in their zone without affecting other areas in the building any time of the year. In multiple-unit installations, under conditions when some heat pumps operate in the cooling

mode while others operate in the heating mode, controls are necessary so that the loop water temperatures remain between prescribed limits.

Benefits

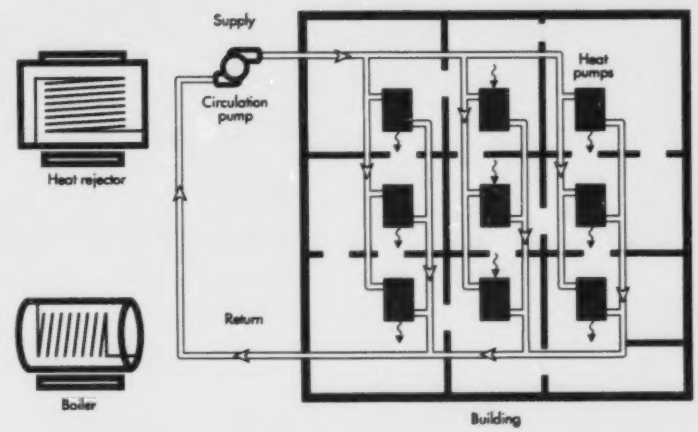
- *Saves Energy* – Permits the opportunity for energy conservation by recovering heat from interior zones and/or waste heat, and by storing excess heat from daytime cooling for nighttime heating.
- *Retrofit Opportunities* – Bulky air ducts or noisy air conditioners can be simply replaced by one pipe loop running throughout the building.
- *Lower Installation/Maintenance Costs*– In new buildings, labour and construction material costs are reduced because most of the systems are factory-packaged. Bulky and costly insulation is not required because the water in the loop remains near room temperature. The total life cycle cost of this system often compares favourably to central systems when considering relative installed cost, operating costs and system life. Units also have a longer expected life than air-cooled heat pumps.
- *Increased Comfort* – Noise levels are lower than air-cooled systems because condenser fans are eliminated.
- *Flexible Operation/Expansion* – Should a unit fail, the entire system is not shut down. For future building changes, larger sized units can be installed easily to handle increased heating and cooling requirements

Winter



Heat is supplied to the water loop by the boiler and absorbed by the heat pumps to provide space heating.

Heavy Core Loads



Any time at least one-third of the units are cooling, enough heat is rejected to the loop to provide all the heat requirements of the perimeter, even in winter.

without costly alterations. Units are not exposed to outdoor weather, which allows installation on the seacoast and in other corrosive atmospheres.

- *Heat Storage Capability* – A water source heat pump system has the capability to be easily modified to "store" heat for later use. By adding a water storage tank into the loop, excess unwanted heat generated during the day can be used to heat the water in the storage tank for use at night, during the weekend or in the morning to return the building to normal operating temperatures. The water in the storage tank can be heated further through electric heaters, which can take advantage of utility off-peak rates. This reduces the peak electrical demand experienced during the day. For cooling purposes, the water may be cooled through the heat rejector and stored for times of high daytime cooling demand.

Candidate Buildings

Heat pumps should be considered whenever a building needs both heating and cooling. Depending on the building layout, the installed cost of a WLHP with one unit per zone is likely to be lower than a system with one central heat pump serving a whole building. Long operating hours, high lighting requirements and low window-to-wall area ratio are conditions favouring the selection of a heat pump. Also, buildings requiring individual metering of heating and cooling will benefit. The system flexibility allows units to be upgraded or down-sized to accommodate changing tenant requirements.

Example

Water loop heat pumps were the system of choice for a heating and cooling retrofit of an office building in downtown Toronto. The eleven storey building had a gross floor area of 70,000 square feet and was built in 1952. In 1985, the outdated and unreliable HVAC system was upgraded. The original heating and cooling system consisted of perimeter fan coil units supplemented by a central fresh air system. Cooling was provided by central reciprocating chiller which had a history of frequent failure. Heating was provided via steam which was purchased from an outside source. The new system consists of 135 interconnected perimeter heat pump units averaging 3/4 ton in size and 18 interior units of three and a half tons each that are hidden in closets. The heat pump total energy costs following the retrofit averaged less than $1.30 per square foot – a savings of more than $10,000 annually.

For further information please contact:
Industrial, Commercial and Institutional Programs, Natural Resources Canada,
580 Booth Street, 18th Floor, Ottawa, Ontario K1A 0E4, Fax: (613) 947-4121

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ENERGY EFFICIENCY

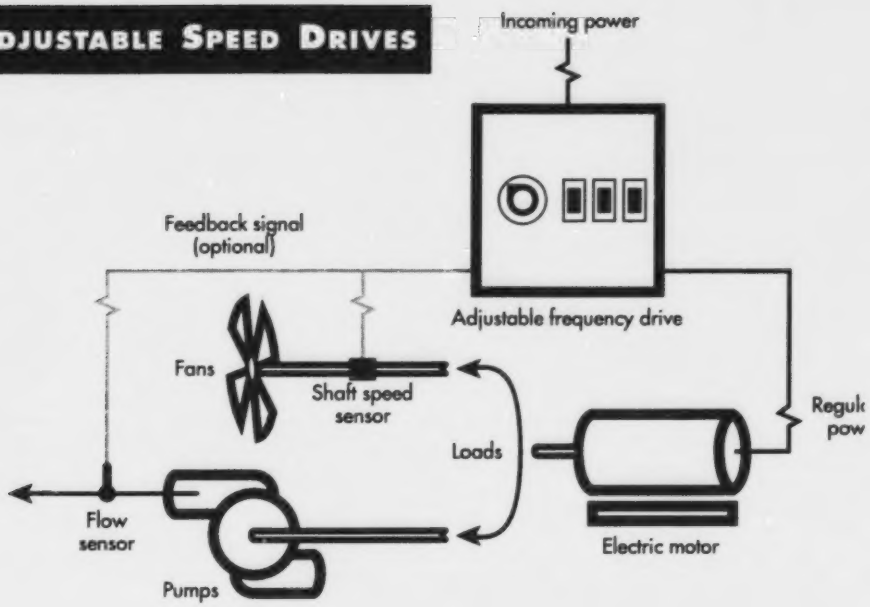
ADJUSTABLE SPEED DRIVES

Approximately 50 per cent of the electricity used in commercial buildings is consumed by electric motors. Energy reduction strategies for motors can be placed in three general categories:

- Reduction in motor electricity consumption by decreasing the load. In many existing buildings, there has been considerable over-design in air and water flow systems. By re-evaluating and trimming the flow rates being produced by pumps and fans, the power drawn by the motor is reduced by approximately the cube of the flow rate.
- Reduction in hours of operation. Energy consumption can be decreased by careful review of the required hours of equipment operation along with the installation of energy management control systems which can automatically shut off fans and pumps when they are not needed.
- Application of new or improved technologies such as high efficiency motors and adjustable speed drives (ASD).

ASDs are used in applications where the speed of the motor driven equipment needs to vary instead of operating at a constant speed all day. They are employed in order to match the motor output speed and device requirements. Mechanical drives are one type of ASD, but they suffer from lower efficiency, a smaller speed control range, bulky size and higher maintenance requirements.

The remainder of this fact sheet will concentrate on electronically based ASDs which are often referred to as adjustable frequency drives or variable frequency inverters. They are essentially devices which control the speed and torque of AC electric motors. This is done by passing the input power through a black box, which varies the input frequency and the speed of the motor. The output of the ASD can



be varied in response to manual control or an automatic control signal in the form of a voltage, current, or pressure.

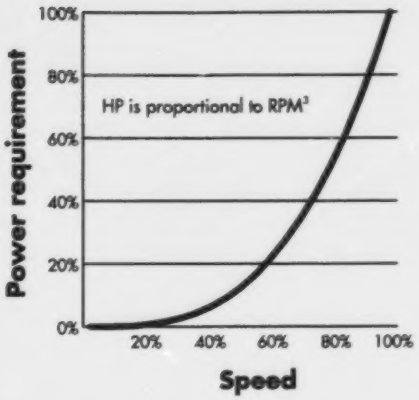
Physically, variable frequency drives are comprised of many electrical circuits and components that are usually arranged within a cabinet which provides heat dissipation and shielding. Drives vary greatly in size, depending upon horsepower, voltage rating and type. Electrical cables connect the motor to the drive, which may involve a considerable distance. Small AC drives can be built on to their associated motors. There is a small energy loss within the "black box" components, making ASDs slightly less than 100% efficient.

ASD Technology – How it Saves Energy

When an electric motor is driving a piece of equipment such as a centrifugal pump or a fan, the speed that the motor shaft is turning directly affects the electricity consumption.
Energy consumed by motor (HP) is proportional to the cube of the shaft speed (RPM)3

For example, a reduction in motor speed of 10% results in a 27% reduction in power requirement. The problem with conventional fixed speed AC systems is that if a reduction in the load occurs, excess energy is wasted in the control device (dampers, throttling valves, recirculation loops) since the power delivered does not decrease in proportion to the reduction in demand. By introducing an ASD, the speed of

Speed – Power Relationship



loads can be adjusted so that overall energy and peak power savings can be achieved.

ASD Applications and Economics

The majority of ASDs operate on variable air volume fan systems. They are also used with fluid pumping applications and air-conditioning chillers. This makes them suitable for both new and retrofit installations. Typical savings for commercial buildings are about 60% of the constant speed motor energy consumption.

ASDs are presently available from many manufacturers in sizes ranging from 1 to 1500 horsepower. The design of an ASD is site specific, so the equipment must be chosen to suit the particular application.

The cost of an ASD varies depending on the size of motor controlled. For motors of less than 5 HP, prices range from about $600 to $2500 per HP. For very large motors (100 to 300 HP) the cost is reduced to a few hundred dollars per HP. The cost of an ASD is typically paid back in 5-10 years and can be paid back sooner when applicable utility incentives are used. For applications above 50 HP, installation costs are usually comparable to the total capital cost for the drive. Below this power rating, installation costs may be as much as double the drive cost.

Other advantages of an ASD over mechanical, hydraulic and fixed speed drives are:

- wider speed, torque and powe ranges
- shorter response times
- equipment life improvement
- reduction in vibration and noise levels
- reduced maintenance and downtime

There may be savings in terms of both energy consumed and peak demand charge. The extent of these savings depends on the local utility's rate schedule. Care must be taken to consider both energy and demand savings-often economic calculations are made using the average cost of energy resulting in significantly overstated saving estimates.

The demand charge forms the other element of electrical power cost. It compensates the utility for the peak current it must deliver during the month. The most significant factor affecting the demand charge is the maximum load incurred by the customer. Since the load, which varies with the cube of speed, can be adjusted by ASDs, significant demand charge savings are achievable.

For further information please contact:
Industrial, Commercial and Institutional Programs, Natural Resources Canada,
580 Booth Street, 18th Floor, Ottawa, Ontario K1A 0E4, Fax: (613) 947-4121

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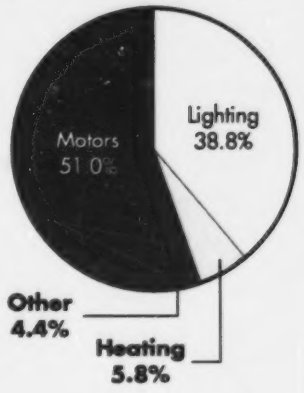
ENERGY EFFICIENCY

ENERGY EFFICIENT MOTORS

An electric motor is a device that converts electrical energy into mechanical energy. Approximately 50% of the electricity used in commercial buildings is used by electric motors. Their primary uses are for refrigeration, air-handling and elevator equipment. The cost of electricity to run a motor for one year is often many times the purchase price, meaning small improvements in motor efficiency can yield significant savings.

Distribution of Commercial Electricity Use

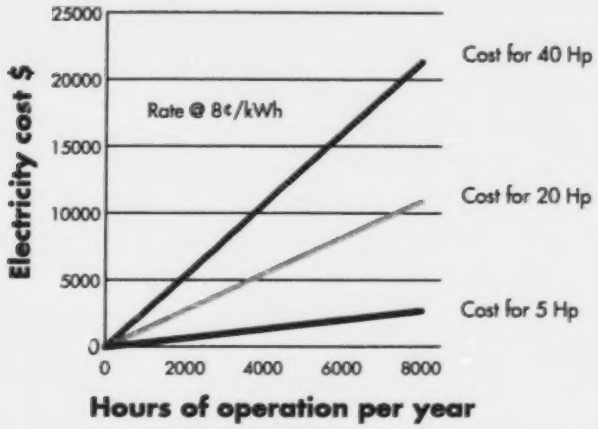


There are many types of motors. The main classifications are Alternating Current (AC) Motors, Direct Current (DC) Motors and Universal Motors. For commercial HVAC equipment, motors are commonly powered by AC. DC motors are used in applications where precise speed control is required.

ENERGY EFFICIENT MOTOR TECHNOLOGY – HOW IT SAVES ENERGY

Electric motors are generally efficient, but with rising power costs the demand for even more efficient models has led to the development of the High Efficiency Motor. The efficiency of a motor is the ratio of its mechanical output to electrical input. Power input to the motor is either transferred to the shaft as power output or is lost as heat through the body of the motor. By using better grades of materials and improved designs these losses have been reduced. A high efficiency motor produces the same mechanical output power using less electrical input power than a standard motor.

Operating Costs of Electrical Motors



These costs are for standard motors with the following efficiency: 40HP-89.5%, 20HP-87.5%, 5HP-88%

Application Considerations

Energy efficient motors can be used wherever conventional motors are used. They will have the same specifications as the standard motors and come in the same frame sizes. There is a broad line of energy efficient motors with different powers, enclosures, torques, insulation and speeds. Energy efficient motors are considered an economical replacement for existing failed motors. It is not usually viable to replace standard motors that are operating satisfactorily, although in some cases detailed economic analysis may prove otherwise. As a rule of thumb, the economics of retrofitting with high efficiency motors are favourable where electric motors use up to 50% of all electricity.

In order to fully maximize investment in high efficiency motors, it is very important to size the motor so it matches the load as closely as possible. Peak efficiency occurs between 75% and 100% of full load depending on design, and drops significantly below about 30%. If the speed of the motor driven equipment needs to vary instead of operating at a constant speed, then the use of an adjustable speed drive should be considered.

High efficiency motors are more expensive because they use more and better materials. Price increases are 20-25% for smaller motors (1-20 HP) and 5-10% for larger motors (up to 200 HP). For this reason they should be selected when the premium paid in excess of a standard efficiency motor is recovered over a reasonable period of time. Applications with high annual running hours and average to high loading are good candidates.

THE BENEFITS

A high efficiency motor can reduce electricity consumption by 3% to 8% over standard motors with efficiency gains as high as 12% in the 1HP range. There could also be a demand savings associated with the use of a high efficiency motor if it operates during electrical peak periods.

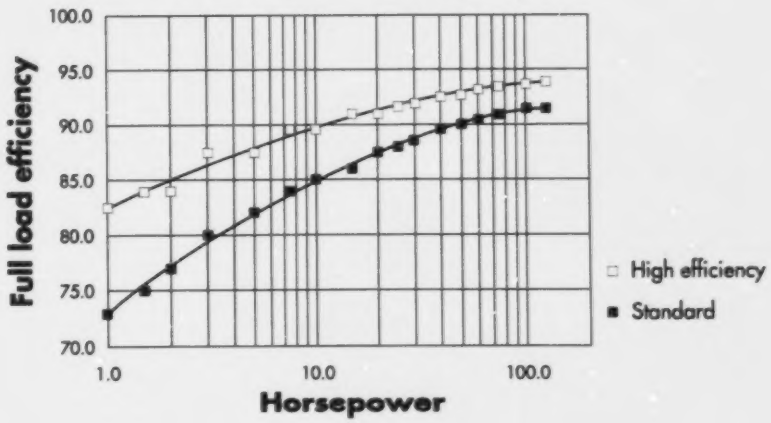
Since the motor is more efficient, it generates less internal heat and runs cooler. This will contribute to longer life and further savings through reduced air-conditioning. Newer motors are also quieter, last longer and are generally more reliable.

Because "Energy efficient" motors contain more material, stator and rotor losses are minimized by reducing the resistance of their respective windings. This is achieved by increasing the cross sectional area.

Another factor to keep in mind when doing retrofit work or considering the replacement of existing motors is to take advantage of cash incentives offered by some utilities.

In the commercial sector, motors are often purchased by original equipment manufacturers (OEMs) for use in packaged equipment. The OEM, not being responsible for operating costs, often opts for the lowest capital cost motor which usually results in low efficiency. Participants in the FBI should encourage their management firm to specify high efficient motors in all retrofit equipment.

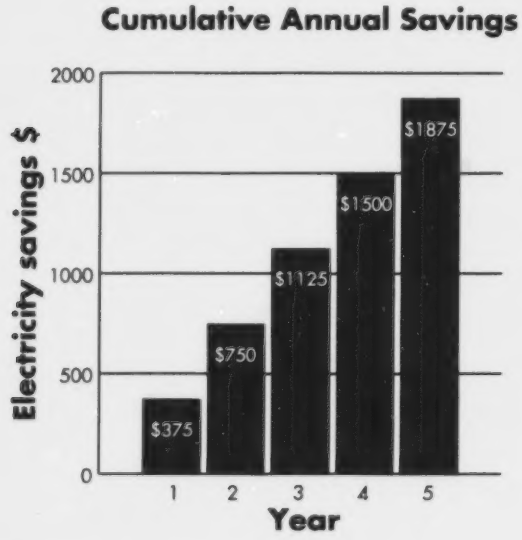
Speed – Power Relationship



EXAMPLE

Replace a 25 HP fan motor with a high efficient unit. The fan operates 16 hours per day, or 5480 hours per year and the average electrical energy cost is $0.06 per kWh.

Standard Motor = 85% efficient
High Efficiency Motor = 90% efficient
Incremental Cost = $305
Energy Savings = $427 per year
Payback period = 9 months



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ENERGY EFFICIENCY

ADVANCED WINDOWS

Windows play an important role in achieving a high quality indoor environment. Like any part of the building envelope, a window is a filter of conditions between the inside and the outside environments. Windows have long been a weak point in the building envelope and are only now benefiting from significant improvements in energy-efficiency, comfort, and durability.

Heat losses through windows represent a major load for both heating and cooling systems. Window manufacturers are exploring and introducing radical improvements to performance while preserving the daylighting benefits.

The main improvements achieved with high performance or advanced windows are the increase resistance to heat flow and the attendant increase in the indoor surface temperature of glazing and frame. The first improvement reduces both heating and cooling costs, while the latter increases thermal comfort conditions and allows for higher indoor humidity without condensation.

Advanced windows offer clear opportunities: reduced heating equipment sizing; reduced heating and cooling energy; design flexibility in utilizing large areas of windows in any direction; improved indoor thermal comfort; and the conservation of resources.

Advanced Window Technology – How it Works

Advances in physics and engineering sciences have resulted in many improvements in window design, performance, and construction. The use of low emissivity coatings on glass or thin plastic film, gases other than air in the cavity between the glass sheets, and evacuated sealed units has resulted in high quality performance

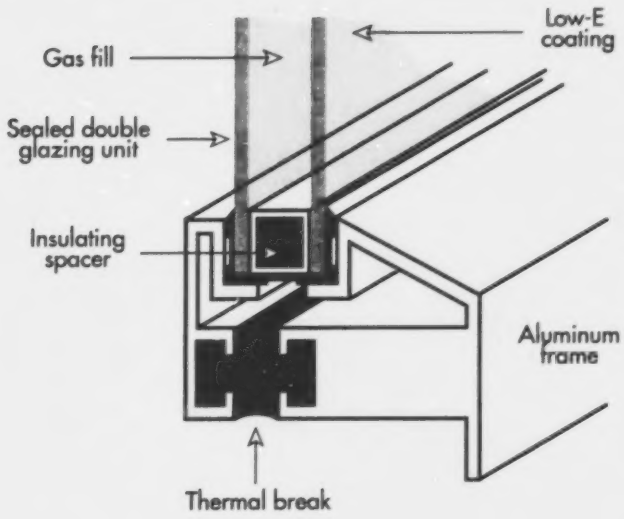
windows. Window frames and spacers are not limited to conventional materials. Vinyl, polyurethane, fibreglass and silicone are now being used for more durable, stronger and better performance windows.

Components of Advanced Windows

The three major components that make up a window are glazing, frames, and spacers.

Glazing

The glazing is the transparent part of the window. Any building with existing single-glazed windows should retrofit with more energy-efficient windows immediately. The glass itself adds practically no thermal resistance to the window as a whole. A simple way to improve glazing performance is to retrofit with new windows that have additional panes of glass and air spaces.



The addition of a second pane, and the creation of an air gap between the panes, reduces the conduction and convection of heat through the glazing unit. Additional glazing increases the unit's thermal resistance. However, this rule shows a diminishing return on increasing the number of glazings. The reason for diminishing reduction of energy loss is that radiation heat loss dominates when more than two panes of glass are used. Multiple glazings are used when there is a condensation problem in high humidity areas.

- *Low-Emissivity Coating* – Emissivity is the ability of a surface to radiate heat. Low-E coatings reduce the emissivity of the glass surface, keeping heat in during the cold winter months, and holding cool air during hot summers. They also control glare by blocking most incoming solar energy and cutting out 99% of the sun's damaging ultraviolet radiation. They reduce up to 65% of the radiant heat loss, and also reflect 60%-80% of solar energy.

- *Window Film* – Window film is the general term used to describe a family of high-tech film products. It is applied to the interior surface of a window, thereby reducing solar heat gain and heat loss through the window glass. The reflective property of window film is attributable to a thin layer of metal particles sandwiched between plastic layers. It reduces heat gain and contributes to the aesthetics of a building's

exterior. A window film can eliminate as much as 79% of the solar heat gain and cooling energy loss that would normally be experienced using clear glass. Window film also reduces glare from the sun and the transmission of ultra-violet radiation through the glazing.

- **Gas-Filled Windows** – The reduction of heat transfer by radiation in low-E windows has focused attention on ways of further reducing convection and conductive heat loss. Air, compared to other gases is a good conductor of heat. By replacing the air between the panes with a heavier gas having lower thermally conductivity, conductive heat loss is reduced.

Frames

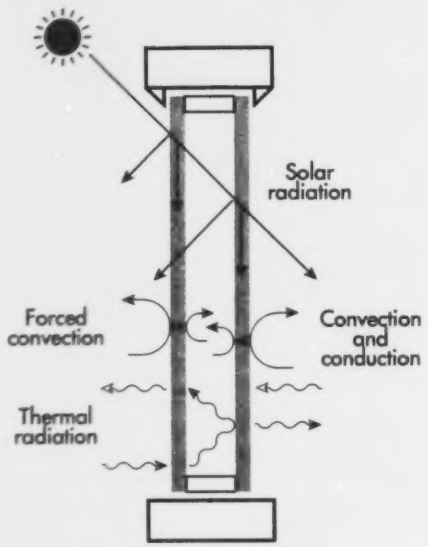
The second major component of a window is the frame. The frame performs the following functions:

- Holds the window in place
- Allows glazings to open and close
- Interfaces the glazings with the wall

Heat Transfer Mechanisms

Convection: The transfer of heat that occurs when a moving gas (like air) or liquid (like water) comes into contact with a surface of a different temperature. For example, hot and cold air are in constant contact with both sides of the window resulting in convective heat transfer.

Conduction: The transfer of heat that occurs by direct contact of materials of different temperatures. The metal frame of a window conducts heat since each end is subjected to different temperature environments. That is why interior surfaces of metal window frames are very cold in the winter months. Energy efficient window frames get around this problem by introducing a thermal break or discontinuity in the metal frame. The gap is replaced by a better insulating material, such as plastic, which reduces the conductive heat losses.



Radiation: The transmission of heat by electro-magnetic waves. Radiation is unique since it is the only form of heat transfer that does not require an intermediate material. Radiation can travel equally well through air or a vacuum. For windows, new coating technologies can help to maximize the radiation energy received from sunlight in the winter and minimize it during the summer.

The important selection criteria for window frames are:

- Thermal integrity
- Infiltration rate
- Aesthetics
- Cost

Window Spacers

All advanced windows have some type of spacer that maintains the separation between the two (or more) panes of glass. The spacer must be strong enough to hold the window apart and provide high thermal resistance.

Operable Windows

Operable windows, incorporating advanced window technology, can provide individual control to supplement or modify the operation of the conventional mechanical heating, cooling and ventilation systems. The lower maintenance and operating costs of these advanced operable windows are more than offset by their increased capital cost of 15%. Opening the windows in the Spring and Autumn seasons to forestall the use of air conditioning systems can increase the human comfort level. The maximum building height for the use of operable windows is eight storeys. The increased quality in hardware and seals will tend to increase the energy efficiency of operable windows to more closely match that of sealed windows.

BENEFITS

- Reduction of annual space heating and cooling costs – savings range from 14% to 24% and depend on building location and window type.
- Elimination of cold spots – decreases condensation problems and avoids use of warm air distribution through perimeter heating systems. Centrally located distribution systems are more effective and economical.
- Reduction in maintenance costs due to greater emphasis on quality assurance by window manufacturers.

COST ANALYSIS

Like many energy efficiency measures, windows also show diminishing cost returns with increasingly sophisticated technology. The selection of a proper window for a medium sized or large building should be assessed on the basis of life-cycle costing and the simple payback period. The potential energy and power reductions achieved through the use of advanced windows should be weighted against the incremental costs and any efficiency incentives.

For further information please contact:
Industrial, Commercial and Institutional Programs, Natural Resources Canada,
580 Booth Street, 18th Floor, Ottawa, Ontario K1A 0E4, Fax: (613) 947-4121

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ENERGY EFFICIENCY

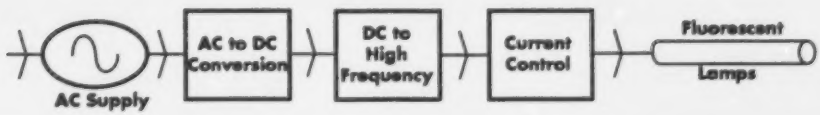
BALLASTS FOR FLUORESCENT LAMPS

The ballast is a critical element of a fluorescent lighting system that controls the power delivered to the lamps. New technology allows ballasts to be more efficient, last longer, have lower maintenance costs, provide better quality light with less noise and give off less heat.

Ballast Technology — How it Works

A ballast controls the voltage required to start up a lamp and the current required to operate the lamp. A ballast serves as a transformer, increasing or decreasing the voltage supplied to the lamp, as required. In so doing, the ballast itself consumes energy, from 6 to 14 Watts. As a result, when lighting levels are reduced by disconnecting lamps, it is also important to disconnect the ballasts, as they will continue to consume energy when powered on, even without any light bulbs. Figure 1 shows the general functions of a ballast.

Figure 1 - The functions of a ballast



There are two basic types of ballasts: electromagnetic, also known as magnetic ballasts (which may be standard or energy efficient) and electronic ballasts. Typically, standard electromagnetic ballasts are used with fluorescent lamps, but the new energy-efficient magnetic ballasts and electronic ballasts are becoming more popular.

- Magnetic ballasts, or core-coil ballasts, consist of a centre core made of layers of steel surrounded by copper or aluminum coils. The copper coils within the energy-efficient magnetic ballasts are designed for greater surface contact; the core is made of higher quality materials.
- Electronic ballast, or solid-state ballasts, use electronic components and are capable of operating lamps at much higher frequencies -- about 20,000-40,000 Hertz (Hz), rather than the 60 Hz used by the magnetic ballasts. At higher frequencies, fluorescent lamps can operate 10-15 per cent more efficiently. The electronic ballasts also have fewer **ballast losses***.

* **Ballast loss** is the amount of energy a ballast loses in the form of heat, vibration and current leakage when operating a fluorescent lamp.

Table 1 provides a comparison of the power consumed by different ballast-lamp systems. The values given are the approximate values for a single ballast operating two T12-40W lamps. Actual values will vary slightly depending on the specific ballast and lamp. Energy-efficient magnetic ballasts use approximately 10 per cent less energy than the standard magnetic ballasts, whereas electronic ballasts use approximately 25 per cent less energy.

Table 1 - Power consumption of ballast-lamp systems (Watts)

	Ballast Type		
Lamp Type	Standard magnetic	Energy-efficient magnetic	Electronic
T12-40W	96 W	88 W	73 W

Advantages of the new ballast technology

The new energy-efficient magnetic ballasts and electronic ballasts offer several advantages over the standard magnetic ballasts.

Reduced Electricity Costs

The new ballast technology is more energy-efficient and provides the same, or a greater, amount of light while reducing the cost of electricity. When energy-efficient ballasts are used, electricity demand and consumption are reduced for two reasons. First, the lighting system itself uses less energy. Second, the air conditioning system uses less energy, due to cooling load reductions, since the energy-efficient ballasts produce less heat. (Heating requirements may also increase slightly, but it is better to heat a building with a boiler than with an electric ballast.

Less Noise

Electronic ballasts emit little or no humming sound.

Less Flicker

Fluorescent lamps give off light when a phosphor coating on the inside of the tube is activated. (Refer to the "Fluorescent Lamps" fact sheet.) When operated with electronic ballasts, the phosphor coating in the lamp never deactivates, due to the higher frequencies of operation. Thus, flickering and the eye fatigue associated with it are reduced with the new electronic ballasts.

Longer Life

The life time of a standard ballast operating at 90°C is typically about 12 years, depending on its operating temperature. The higher the operating temperature, the shorter the life of the ballast. If the operating temperature of the ballast is 10°C higher than 90°C, the life time would be shortened by about 50 per cent; while if the operating temperature is 10°C lower, the life time would be approximately doubled. Energy-efficient ballasts operate at cooler temperatures; nearly doubling their life expectations.

Ballast replacement

When ballast failures are frequent or a set of ballasts is approaching the end of its life expectancy, ballast replacement is recommended. To minimize labour costs, ballast replacement should be conducted on a grouped basis. Energy-efficient ballasts should always be considered when ballasts are being replaced or lighting systems are being retrofitted.

There are many factors to consider when selecting a ballast. A ballast must match the voltage of the electricity supplied, as well as

the lamp which it will operate. A ballast should have the following characteristics:

- low ballast losses;
- high **power factor***;
- high **ballast factor***;
- low **total harmonic distortion***;
- class P designation, if the ballast is to be operated indoors. This means that the ballast is thermally protected;
- suitable sound rating – the sound rating is given in letters from A to F, with A being the quietest and F the noisiest; and
- meet ANSI (American National Standards Institute) specifications — a CBMA (Certified Ballast Manufacturers Association) label indicates that the ballast has met ANSI specifications.

When changing ballasts, consideration should also be given to environmental impact. Ballasts produced before 1979 contain small amounts of PCB's and need to be safely stored before the PCB's are destroyed. New ballasts are PCB-free. The Ministry of the Environment should be contacted for information on the proper handling of ballasts containing PCB.

* **Power factor** is the ratio of the portion of power that actually performs work (measured in kilowatts (kW)), known as resistive power, to the total apparent power (measured in kilovolt-amps (kVA)). Power factor is a number between 0 and 1, with numbers closer to 1 being better. Utilities usually charge a penalty when the overall power factor for the electricity delivered to a client drops below a particular value.

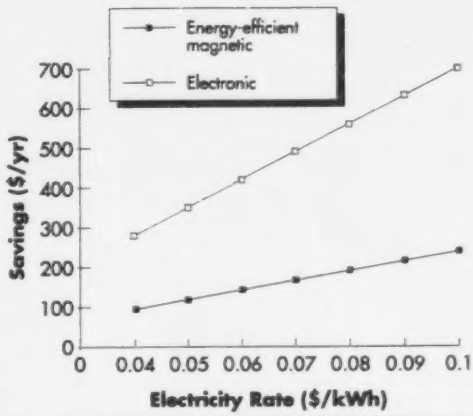
* **Ballast factor** is the amount of light provided by the ballast-lamp system divided by the amount specified for the lamp by the lamp manufacturer.

* **Total harmonic distortion (THD)** is a measure of the distortion caused by harmonics, high frequency components of electronic waves. When a ballast is operating, it may generate harmonics that can interfere with sensitive electronic equipment such as computers. Due to technological improvements, today's ballasts produce less harmonics then their predecessors.

EXAMPLES OF SAVINGS

Figure 2 shows the annual savings in lighting costs by replacing 100 standard magnetic ballasts with either energy-efficient magnetic or electronic ballasts. For this example, each fixture is assumed to operate two T12-40W lamps (with power ratings as indicated in Table 1) for 3000 hours per year. The savings are greater when the electricity rates are higher.

Figure 2 - Annual lighting savings for retrofitting 100 standard magnetic ballasts with new ballast technology



In 1993, commercial customers in Canada paid between $0.045 to $0.11 a kilowatt-hour (kWh), including taxes and demand charges. In the previous example, using 1993 rates, a commercial customer in Canada would save between $100 and $200 annually by switching to energy-efficient magnetic ballasts and between $300 and $700 by switching to electronic ballasts.

Conclusions

To properly evaluate different ballast-light systems, the life-cycle cost should be calculated for the various options. Life-cycle cost would include the capital and installations costs, as well as operating and maintenance costs, taking into account any financial incentives offered by the local utilities. Such an analysis should also include savings due to a reduction in air conditioning load.

For further information please contact:

Industrial, Commercial and Institutional Programs, Natural Resources Canada,
580 Booth Street, 18th Floor, Ottawa, Ontario K1A 0E4, Fax: (613) 947-4121

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June 1994

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ENERGY EFFICIENCY

COMPACT FLUORESCENT LAMPS

Compact fluorescent lamps are an energy-efficient, long-lasting substitute for common incandescent lamps. Their excellent quality of light output and their wide variety of available sizes, shapes, and wattage make them ideal candidates in retrofit situations.

Although fluorescent lamps have dominated the commercial building sector, their large physical size (long tubes and ballasts) makes them impractical in areas where incandescent bulbs have been used. In the early 1980s, new technical advances "shrank" the fluorescent lamp and opened up a huge new market.

Compact Fluorescent Technology — How it Works

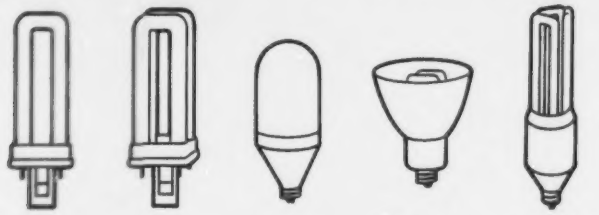
As with a standard fluorescent lamp, a compact fluorescent lamp consists of a sealed glass tube coated on the inside with phosphor or fluorescent powder and filled with a mixture of low pressure gas (such as argon or neon) and mercury vapour. Electrodes are placed at each end of the tube. (Refer to the "Fluorescent Lamp" fact sheet for more information on fluorescent lamps in general.) Unlike the standard fluorescent lamp, a compact fluorescent's glass tube is bent so that the electrodes are at one end of the lamp.

Compact fluorescent lamps operate in the same manner as full-sized tubes. When a specified voltage is applied to the lamp, electrons flow from the electrode at one end of the tube to the electrode at the other end. When the electrons cllide with the mercury atoms, energy is absorbed and then released by the mercury atoms. The released energy strikes the phosphor coating and is converted into heat and visible light.

Compact fluorescent lamps consist of small diameter tubes: T4s have 1/2" diameter tubes and T5s have 5/8" diameter tubes (the number after the letter 'T' represents the diameter of the tube in eighths of an inch). A smaller tube diameter allows the use of thicker, more economical phosphor coatings in compact fluorescent lamps, thus increasing the light output.

Common shapes encountered today are single- and double-folded U-shaped tubes, known as twin and quad tubes, respectively. Some of the new lamps even have triple-folded tubes.

Figure 1 - Some common compact fluorescent lamps



Compact fluorescent lamps may also be globe-shaped or include reflectors.

Every fluorescent lamp requires a ballast to start the lamp and regulate the voltage during operation. (Refer to the "Ballasts for Fluorescent Lamps" fact sheet.) Sometimes the ballast is part of the compact fluorescent lamp itself.

- *Integrated compact fluorescent lamps* contain a built-in ballast and fit directly into almost any standard incandescent lamp socket. When replacing the lamps, the entire unit must be replaced.
- *Modular compact fluorescent lamps* do not include a ballast and must be plugged into a specially designed ballast and socket. Modular lamps plug into adapters which contain the ballast and screw into incandescent lamp sockets.

Advantages of the Technology

Reduced Energy Costs

Compact fluorescent lamps reduce energy costs in two ways:

1. Direct savings in electricity. Both electricity demand and consumption charges may be reduced by using compact fluorescent lamps. They have higher **efficacies*** — that is, they emit between three and four times more light than incandescent lamps. (Ranging from 25 and 85 lm/W; as opposed to 8 and 20.)
2. Indirect savings from reduced air conditioning load due to lower internal heat gains in the building. Compact fluorescent lamps convert approximately 70 per cent or more of the energy they consume to light, with less than 30 per cent going to heat. Incandescent lamps convert only 10 per cent of energy to light, with 90 per cent going toward heat. (Heating loads may also increase, but this is not usually a major concern in commercial buildings where there are large internal heat gains and cooling loads are more of a concern.)

Reduced Maintenance Costs

A compact fluorescent lamp has a lifespan about 10 times longer than a standard incandescent lamp. Compact fluorescent lamps are rated for between 10,000 and 20,000 hours of operation, while incandescent lamps compare at between 750 and 2,000 hours. Longer lives mean fewer lamp replacements and lower maintenance costs.

Good Colour

Compact fluorescent lamps have high **colour rendering indices* (CRIs)**, with CRIs in the eighties.

* **Efficacy** is a measurement of the efficiency of a lamp. It is the amount of visible light output by a lamp divided by the power input and is measured in lumens per watt (lm/W).

* **Colour Rendering Index (CRI)** is one of the measures used to describe the quality of a light source. It indicates the effect that a light source has on the colour appearance of objects. The CRI has a value between 0 and 100. CRIs in the range of 75 to 100 are considered excellent, while CRIs from 60 to 75 are considered good.

Applications

Compact fluorescent lamps come in sizes from 5 to 30 W and can replace 25 to 150 W incandescent lamps for many commercial building uses. They may be used in wall and ceiling mounted fixtures, exit and directional signs, floodlights, display lighting, or task lighting. Compact fluorescent lamps are suitable wherever precise beam control is not required, although there are some newer models which can be suitable for these applications. Several factors should be taken into account when considering compact fluorescent lamps.

Fixtures

Compact fluorescent lamps are best suited to open fixtures. Some fixtures, which were designed for the smaller incandescent lamps, may not be large enough for the fluorescent lamp and ballast.

Operating temperatures

As well, fluorescent lamps should not be used in fixtures that will trap heat. Fluorescent lamps are very sensitive to their operating temperatures. Warm temperatures reduce the light output and operating the lamps much below room temperature will also affect their operation and should be avoided. In general, fluorescent lamps are not suited for outdoor use.

Hard-wire ballast

In some applications, users may wish to hard-wire the ballast into the fixture to prevent the compact fluorescent lamps from being replaced with incandescent lamps.

Example of Savings

One hundred 40 W (.04 kW) incandescent lamps that operate for 4000 hours a year are replaced with compact fluorescent lamps which consume 10 W (.01 kW) each, including the ballast.

The following equation is used to determine the annual energy savings for the new lighting system. Note that the units for the energy savings per fixture are in kilowatts (kW) to correspond to the electricity rate which is typically given in dollars per kilowatt-hour (kWh).

$$\text{Annual Energy Savings (\$/year)} = \text{Number of Fixtures} \times \text{Energy Savings per Fixture (kW)} \times \text{Hours of Operation (hours)} \times \text{Electricity Rate (\$/kWh)}$$

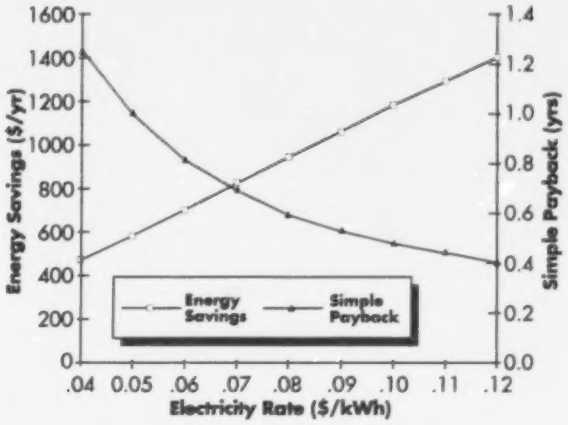
Figure 2 shows the amount of savings in lighting energy costs which can be achieved by replacing incandescent lamps with compact fluorescent lamps in the example above. The amount of savings depends on the electricity rate; the higher the rate, the greater the savings. In 1993, commercial customers in Canada were paying between $0.045 to $0.11 per kilowatt-hour (kWh) of electricity, including taxes and demand charges. In other words, depending on the electricity rate, retrofitting to compact fluorescent lamps for this particular example would provide between $550 and $1,300 of savings per year.

Table 1 compares the capital costs, including installation costs, for compact fluorescent systems and incandescent lamps. Since compact fluorescent lamps last ten times as long as incandescent lamps, ten incandescent bulbs would be required for every fluorescent bulb – a total of one thousand incandescant bulbs for the 100 fixtures being retrofitted.

Table 1 - Capital costs for compact fluorescent lamps and incandescent lamps

	Wattage (W)	Lamp Cost ($/lamp)	Installation Cost ($/lamp)	Total Cost per lamp ($/lamp)	Total Cost ($/n lamps)
Compact fluorescent	10 W	$20.00 (incl. ballast)	$1.00	$21.00	$2,100/100 lamps
Incandescent	40 W	$0.50	$1.00	$1.50	$1,500/1000 lamps

Figure 2 - Annual lighting energy savings and simple payback for replacing one hundred 40 W incandescent lamps with 10 W compact fluorescent lamps



In this example, the compact fluorescent lamps cost $600 more than the incandescent lamps, including installation costs. The simple payback would be calculated as follows:

$$\underset{\text{(years)}}{\text{Simple Payback}} = \frac{\underset{\text{(\$)}}{\text{Extra Capital Cost}}}{\underset{\text{(\$/yr)}}{\text{Annual Energy Savings}}}$$

As shown in Figure 2, the payback period varies from six months to one year, based on 1993 electricity rates in Canada. It must be realized that simple payback calculations should only be used to estimate the potential for savings. A complete analysis would also consider interest rates, as well as the savings due to reduced air conditioning load and any financial incentives that may be offered by local utility.

For further information please contact:

Industrial, Commercial and Institutional Programs, Natural Resources Canada
580 Booth Street, 18th Floor, Ottawa, Ontario K1A 0E4, Fax: (613) 947-4121

References

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ENERGY EFFICIENCY

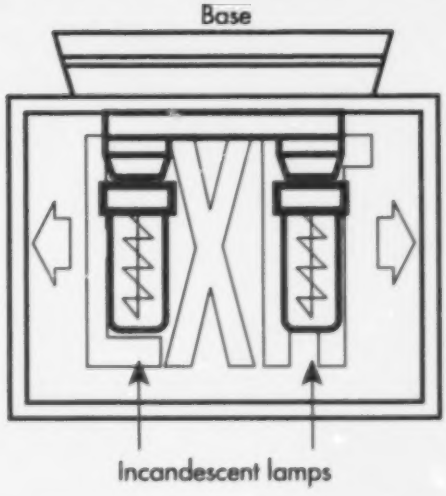
EXITS SIGNS

Incandescent lamps are the most common light source found in exit signs. With a short bulb life and 8760 hours of operation a year, the maintenance and energy costs associated with keeping these lights on are significant.

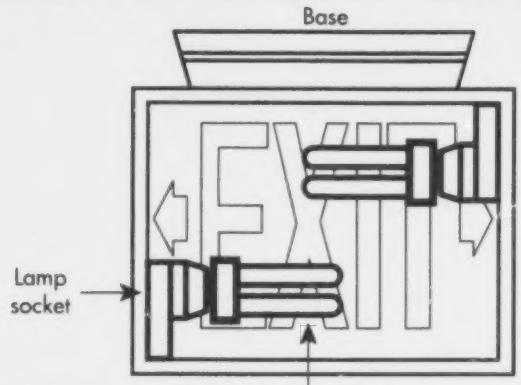
Incandescent Signs

Incandescent signs usually contain two 15 to 25 watt bulbs and consume approximately 30 to 50 watts of power. The capital cost varies from $30 to $130 for lamp and fixture, due to product options such as vandal proofing, internal battery and aesthetic features. The lighting of each letter in the sign tends to be uneven and bulb life is short – generally 1 - 6 months.

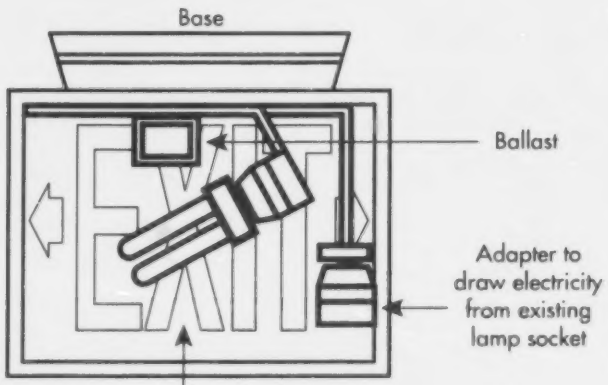
Conventional incandescent lamps



Compact Fluorescent Lamps



Hardware Lamp



Retrofit Lamp

Other more energy efficient lamps are available to replace incandescent lamps in exit signs. These include:

Compact Fluorescent Signs

These are currently the most popular replacement. Existing exit signs can easily be retrofitted with compact fluorescents if there is sufficient space inside the sign to accommodate the lamp and ballast. Kits are available for hard wire replacements or a screw-in adapter and lamp could be used.

New exit lamps designed especially for compact fluorescent are also on the market. Compact fluorescent lamps of 5, 7 and 9 watts provide lighting levels similar to incandescent lamps of 25, 40 and 60 watts respectively. They are more expensive than incandescent – $120 to $300 for lamp and fixture – and the

lighting of each letter is not uniform. Lamp life is generally 1 - 2 years (depending on the type of lamp used). They consume approximately 12 to 20 watts of power.

LED and Miniature Incandescent Signs

These signs are generally quite expensive ($90 to $150). The LED (light emitting diode) sign contains LEDs in plastic tubes which actually form the letters. The Miniature Incandescent Sign contains bulbs in plastic, with a black and red face which form the letters.

Both the LED and Miniature signs use plastic as the medium to transmit the light. They require less depth than incandescent and compact fluorescent signs. They provide a more uniform illumination of letters, are aesthetically pleasing and consume approximately 2 to 10 watts of power. LED signs are still considered a new, emerging technology and are not commonly used in today's market.

Tritium Gas Signs

The illumination principle of a tritium gas sign is similar to that of a television. Radioactive tritium gas undergoes beta decay, releasing an electron which strikes a phosphor-coated tube, shaped into the word EXIT. A modern tritium exit sign uses 25 Curies (about 2.5 milligrams of tritium in the gaseous form) and does not consume electricity. It has a high initial cost but requires very little maintenance. Although lamp life is 10 to 20 years, tritium gas signs are not yet widely used because of their high purchase price. The capital cost for a lamp and fixture is approximately $325. When old tritium gas signs are being replaced with new signs, it is recommended they be returned to the manufacturer who will dispose of the radioactive components free of charge.

	Incandescent Lamps	Light Emitting Diode	Compact Fluorescent
# of Lamps Per Sign	2	—	1
Total Power Consumed	50 watts	4.5 watts	10 watts
Energy Cost Per Year	$35.04	$3.15	$7
Energy Cost (over 25 years)	$876	$79	$175
Rated Lamp Life (hrs)	2,000	219,000	10,000
Bulb Changes (over 25 years)	220	0	22
Lamp Replacement Cost Per Year	$17.50	$0	$15
Lamp Replacement Cost (over 25 years)	$436	$0	$374
Net Savings Per Year		**$49**	**$31**
Simple Payback Period		**1.9 years**	**1 year**
Conversion Cost *(includes installation)*	—	$95.00	$31.00

Life Cycle Comparisons

In the table above, the life cycle costs of energy efficient exit signs are shown in comparison to a standard incandescent sign. Operating time is 8760 hours a year and the electrical rate is assumed to be 8¢/kWh. Note that these costs do not include labour savings or rebates.

Benefits

Converting from incandescent to energy efficient exit signs will result in the following benefits:

- ***Reduced Electricity Costs*** – Direct savings of up to 80% because the lights use less energy.
- ***Reduced Maintenance Costs*** – A longer lamp life means fewer replacements.
- ***Reduced Air-Conditioning Loads and Operating Costs*** – When light is emitted, heat is generated. With an energy efficient lighting system, more energy is converted to light and less to heat.

For further information please contact:
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580 Booth Street, 18th Floor, Ottawa, Ontario K1A 0E4, Fax: (613) 947-4121

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ENERGY EFFICIENCY

FLUORESCENT LAMPS

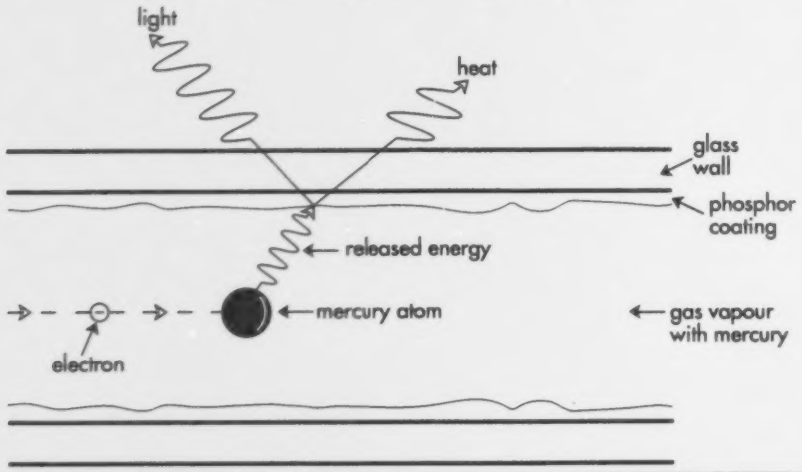
Fluorescent lamps form the backbone of lighting in commercial buildings in North America. Fluorescent lighting consumes over 30 per cent of the electricity used in office buildings. Without sacrificing lighting quality, lighting energy costs in buildings may be reduced by more than 30 per cent by retrofitting to new fluorescent lighting technologies.

A fluorescent lighting system consists of fluorescent lamps, a luminaire (fixture with a reflector), and a ballast (for controlling the voltage and current used to power the lamps). This fact sheet focuses on the fluorescent lamps; ballasts and reflectors are discussed in other fact sheets.

Fluorescent Technology — How it Works

A typical fluorescent lamp consists of a sealed glass tube coated on the inside with phosphor or fluorescent powder, filled with a mixture of low pressure gas (such as argon or neon) and mercury vapour, and with electrodes at each end.

Figure 1 - How a fluorescent lamp works



When a specified voltage is applied to the lamp, electrons flow from the electrode at one end to the electrode at the other end. When the electrons collide with the mercury atoms, energy is absorbed and then released. The released energy strikes the phosphor coating and is converted into heat and visible light.

Advantages of the New Fluorescent Technology

More efficient — saves on energy costs

Today's new fluorescent lamps have a higher **efficacy*** which means that more light is output for the same power input.

- Krypton gas in the tubes allows the lamps to operate at lower voltages.
- Rare earth phosphors are used in combination with conventional phosphors in a two-coat process, resulting in the production of more light and less heat.

Thus, not only are energy costs reduced directly for the lighting, but indirectly for cooling loads, since the building's internal heat gains are reduced. (Heating loads may also increase, but it is better to heat a building with a boiler than with an electric light.

Better quality of light

The new fluorescent lamps also have a higher **colour rendering index (CRI)***. In the past, fluorescent tubes had relatively low CRIs, typically between 50 and 70. Now with the new phosphor coatings, CRIs of over 80 are attainable. Triphosphor T8 lamps, for example, offer CRIs of 75 to 86. The new fluorescent lamps also come in a variety of **colour temperatures***.

Greater lumen maintenance

Though not all of the new fluorescents last as long as the standard F40s which have a **rated life*** of 20,000 hours, some have a greater lumen maintenance. This means that the quantity of light output is maintained for a longer percentage of the lamp's rated life. When designing any lighting system, the fact that lumens decrease over time must be considered.

* **Efficacy** is a measurement of the efficiency of a lamp. It is the amount of visible light output by a lamp divided by the power input and is measured in lumens per watt (lm/W).

* **Colour Rendering Index (CRI)** is one of the measures used to describe the quality of a light source. It indicates the effect that a light source has on the colour appearance of objects. The CRI is a value between 0 and 100. CRIs in the range of 75 to 100 are considered excellent, while CRIs from 60 to 75 are considered good.

* **Colour temperature** is another measure for the quality of a light source. It is a measure of the colour of a light source. Incandescent lamps have a low colour temperature, about 2800°K, and appear yellowish-red; while daylight has a high colour temperature, about 6000°K, and appears bluish. The colour temperature is not directly related to the CRI; a fluorescent lamp with a CRI of 85 may come in a colour temperature of 3000°K, 3500°K or 4100°K.

* The **rated life** is the time at which 50 per cent of the lamps would fail. At about 40 per cent of the rated life, some of the lamps start to fail. At about 70 per cent of the rated life, lamps are usually replaced as a group, rather than just replacing them individually as they fail.

Manufacturers usually rate fluorescent lamps assuming three hours of operation for each start up. If more hours are assumed for each start up, the rated life would be longer. Be sure to compare the rated lives of lamps assuming the same number of operating hours for each start up.

Question: *Should I turn off fluorescent lamps for a short period of time?*

Many years ago, when electricity cost less than one sixth of what it does today, it was considered more cost effective to leave fluorescent lights on all the time. Since turning a fluorescent lamp on and off reduces its lifetime, it was believed that the extra energy cost for operating the lamps when they were not needed was worth the increase in the lifetime of the lamps. Now with the higher cost of electricity and longer lasting lamps, it is better to turn off fluorescent lights when they are not needed, even for short periods of time.

Factors to Consider When Selecting Fluorescent Lamps

Different sizes and shapes

Aside from the differences in lumen output, efficacy, CRI and colour temperature, other factors need to be considered when selecting a fluorescent lamp. Fluorescent lamps come in different shapes and sizes:

- They may be circular, U-shaped, tubular (linear) or compact (Compact fluorescent lamps are discussed in more detail in another fact sheet.);
- Sizes range from as little as 4 Watts (W) to larger than 200 W;
- Diameters may be as small as 5/8 of an inch or larger than 2 inches; and
- Tubular lamps may be anywhere from 6 to 96 inches long.

Different end connections

As well, fluorescent lamps have different end connections, or bases, depending upon the type of circuit in which they are used. Preheat or rapid start lamps have two electrical contacts at each end. These lamps take a few seconds after being turned on to warm up. Slimline or instant-start lamps have only one electrical contact at each end and, as the name indicates, start up instantaneously.

Table 1 - Some typical fluorescent lamp codes

Code	Meaning
Tn	Tubular lamp with a tube diameter of n eighths of an inch
Fn	Fluorescent lamp where n refers to either the wattage or the length of the tube in inches.
CW	Cool white colour
WW	Warm white colour

Temperature limitations

Most fluorescent lamps need to be operated at room temperature.

Manufaturers' product code

The manufacturers' product code provides information as to the wattage, the size and the shape of the lamp, and sometimes the colour of the light source, though not all manufacturers use the same conventions. Refer to Table 1 for some of the typical lamp codes.

T8-32W Lamp

The T8-32W lamp is a very popular replacement for the standard four foot long F40 (T12-40W) often found in office buildings. When switching from T12s to T8s, the ballasts have to be replaced. The lamp manufacturer should be consulted when selecting the ballast to ensure that the components are compatible. When electronic ballasts are used, T8s use 30 per cent less energy than T12s operating with standard magnetic ballasts.

In Table 2, three different lighting systems are compared. All three types of lamps have rated lives of about 20,000 hours. It is interesting to note that although the energy used by the T12-34W system is less than the F40 system, the efficacy of the system is about the same since less light is produced. The T12-34W lamps, as with other "reduced-wattage" lamps, were developed to reduce energy consumption in locations which were originally designed with too much lighting. No ballast replacements are required when switching from F40s to the 34 W system.

Table 2 – Comparison of different lighting systems

	T12-40W (F40)	T12-34W	T8-32W
Ballast	magnetic	magnetic	electronic
Power (W)	96	79	65
Light output (lm)	6050	5060	5820
Efficacy (lm/W)	63	64	90
Energy cost per fixture* ($/fixture/yr)	$ 17.30	$ 14.20	$ 11.70
Energy cost per area** ($/m2/yr)	$ 4.65	$ 3.85	$ 3.15

* Energy costs assume that electricity costs $.06/kWh and that the lights are operated for 3000 hours per year.

** Energy costs per area assume one light fixture for every square feet (or 27 fixtures/100m2).

Conclusions

Adopting new fluorescent lamp technology involves more than just replacing existing lamps with new ones. Many factors should be considered, such as the lumens required, the efficacy, the impact on the cooling loads, and the colour temperature and the CRI of the light.

Upgrades should ensure adequate light levels and glare control as well as the compatibility of all the components in the system. Life-cycle costing, which includes the capital and installation costs as well as the operating and maintenance costs, should be used to compare the various optio:. ..

For further information please contact:

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June 1994

Part of the Efficiency and Alternative Energy Program

Un élément du Programme de l'efficacité énergétique et des énergies de remplacement

ENERGY EFFICIENCY

FLUORESCENT REFLECTOR FIXTURES

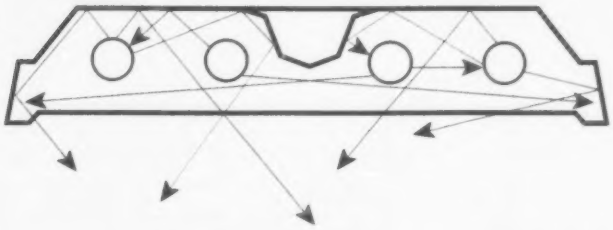
Reflectors are mirror-like devices that can be mounted inside existing fluorescent fixtures to direct light out of the fixture more efficiently. By using reflectors, up to half of the lamps in each fixture can be removed, yielding up to 50% energy savings while reducing light levels only 25-40%.

Fluorescent Reflector Technology – How it Works

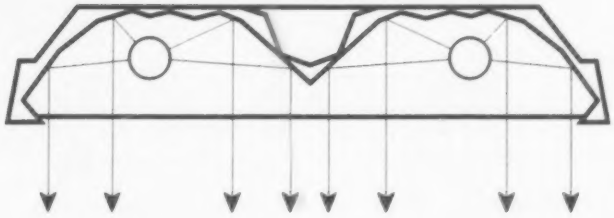
The interior surface of a typical fluorescent fixture has a simple shape with a white enamel paint coating. Inside these fixtures, the light undergoes multiple diffuse reflections and loses intensity before leaving the fixture. In contrast, the complex shape and high reflectance of a custom-designed retrofit reflector causes more light to be directed out of the fixture onto the task, allowing fewer lamps and ballasts to be used in a fluorescent lighting system. The amount of light reflected and its directional behaviour depend upon two characteristics of the reflector material: specular reflectance and total reflectance.

A material with high specular reflectance has a mirror-like finish. A material with high total reflectance minimizes the amount of light absorbed by the surface upon reflection. Properly-designed reflectors redirect the produced light out of the fixtures with a minimum of reflection. The highest performing reflectors also have high total reflectance, meaning that during these limited reflections, only a minimum amount of light is absorbed by the material.

WITHOUT REFLECTOR



WITH REFLECTOR



The three types of reflector on the market are:

- ***Polished Andonized Aluminum*** – these reflectors have a reflectivity of 89-91%. This technology is generally the least expensive and has a life expectancy of about 20 years.
- ***Silver Film*** – this type of reflector contains a thin film of silver that is laminated to an aluminium substrate. Reflectivity ranges between 94 and 97% and the life expectancy is between 10 and 15 years.
- ***Dielectric Coating*** – these reflectors have a dielectric film (consisting of vaporized metals and inorganic dielectric materials) which is vacuum deposited onto anodized aluminium. Reflectivity is 95% and the life expectancy about 25 years.

ADVANTAGES

- ***Reduced Energy Costs*** – Direct savings because fewer lamps and ballasts are used.
- ***Reduced Maintenance Costs*** – Fewer lamp and ballast replacements are required.
- ***Reduced Air Conditioning Load/ Costs*** – With fewer lamps and ballasts giving off heat, reduced cooling costs can add up to 20% of the savings in lighting energy costs.
- ***Extended Ballast and Lamp Life*** – Operating temperatures are reduced since half the number of lamps are used.
- ***Uniform Appearance and Reduced Glare*** – Retrofit reflectors produce uniform brightness and create the image of a lamp in place of the removed lamp. This allows for delamping without impairing fixture aesthetics. The reflector concentrates the light downward, producing the positive effect of decreasing glare at higher viewing angles. This reduces glare and improves visual comfort within the work environment.

Applications

Retrofit reflectors are most commonly used in conjunction with selective delamping. By removing two lamps from a typical four-lamp fixture and installing a reflector, energy use can be reduced by 50% while light output decreases by 25 to 40%.

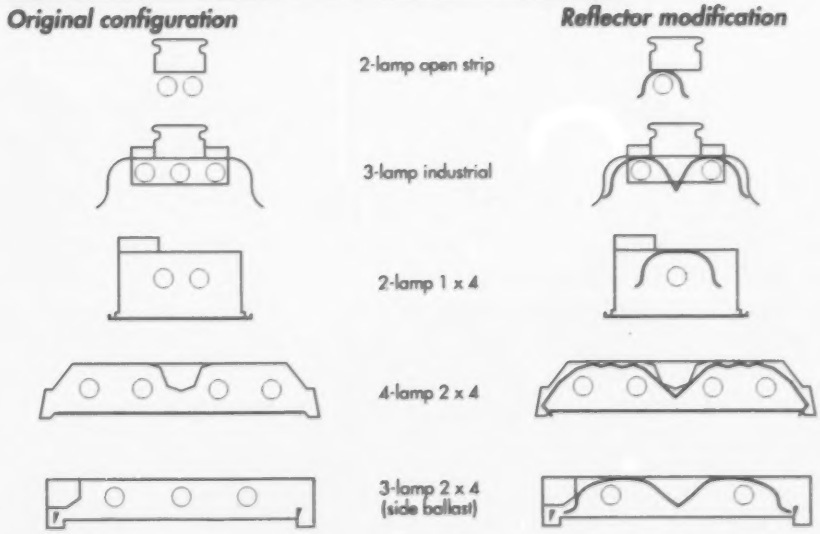
This reduction in light output may be appropriate in spaces that are commonly overlit, based on levels recommended by the Illuminating Engineering Society. In other cases, the reflector can be supplemented with higher output lamps (using a higher output T-10 could recover a third of this lighting loss) and/or improved lenses to recover much of the reduction in light output.

Depending on positioning, the remaining lamps and their sockets may need to be relocated within the fixture to maximize efficiency and improve appearance. In addition, unused ballasts should be disconnected as they continue to draw some power after delamping.

Where existing light levels are too low, custom-designed retrofit reflectors can increase average light levels by 15% or more, depending on the condition of the existing enamel surface. Additional lighting benefits can occur by cleaning the lamps when the reflectors are installed. This simple task alone will boost light output by 5% - 20%. Reflectors can also be used with new energy-efficient fixtures to give ultra-high efficiency lighting

Fixture cost depends on type, size and design of the reflector. The average installed cost of a 2' x 4' recessed aluminium reflector is $50. The average installed cost of a 2' x 4' recessed silver film reflector is $55.

Selected Applications



Note: Reflector installations may not be feasible in some fixtures, such as deep-cell parabolic louver fixtures, due to space limitations or obstructions.

EXAMPLE

A building has 500 fluorescent fixtures, each with four 40-watt lamps. These fixtures can be equipped with reflectors allowing 2 lamps and one ballast to be removed from each fixture.

Existing system – 192 watt fluorescent fixture with 4 40-watt lamps
Replace with – 96 watt Specular Reflector – remove 2 lamps and 1 ballast
Watts saved – 96
% Energy savings – 50

Savings per fixture –	Wattage of existing fixture (watts)	192-
	Wattage of removed lamps (watts)	80+
	Wattage of ballast (watts)	16
	Energy savings (watts)	96
Simple payback –	Capital cost to install reflectors	$29,000
	Annual energy savings	$11,520
	Simple payback	2.5 years

For further information please contact:
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ENERGY EFFICIENCY

HIGH-INTENSITY DISCHARGE LAMPS

The high-intensity discharge (HID) family of lamps are among the most energy efficient light sources available. There are several areas in which incandescent and fluorescent lamps are not the optimum lighting choice. HID lamps offer excellent optical control, very high lumen (lots of light), high efficacy, long life, economical operation and rugged construction. Their bright light makes them better suited for area lighting than task lighting, and they are particularly good for warehouses, outdoor areas and security. Recent advances in the technology have made them attractive for commercial applications such as malls, offices and recreational facilities.

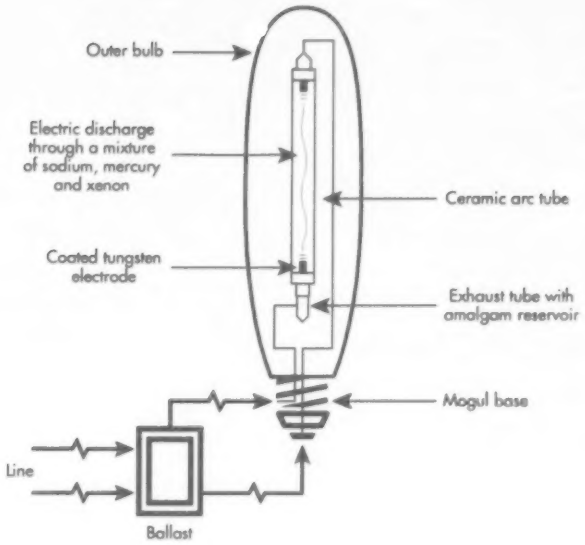
HID lamps are most economical in applications where they operate for extended periods. Their long life makes them ideal for locations where replacement is difficult and they save money in maintenance costs since replacement is less frequent. Their compact size also allows for easier cleaning and less dirt accumulation. Since they require a warm-up period and take time to relight after a power interruption, HID lamps should only be used where such a delay will not cause problems. They are similar to fluorescent lamps in that they require a ballast for starting.

HID Technology – How it Works

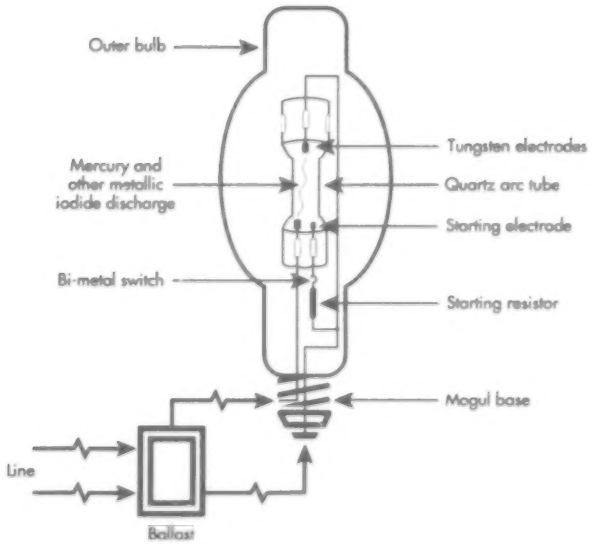
Like fluorescent lamps, HID lamps are considered "discharge" light sources because they produce light by passing an electric current through a vapour. In fluorescent lamps, however, the light is produced by the phosphor coating on the tube walls. In HID lamps, the light is produced by the electric arc itself. The arc discharge also operates at higher pressures and temperatures than in fluorescent lamps – thus the name high intensity discharge.

When a HID lamp is turned on, a small electric arc forms between the starting electrode and the closest main electrode. This changes the starting gas and metal particles into electrically charged ions. When there are enough ions (in other words, when the pressure builds to a

HPS Lamps



MH Lamps



certain level), the main arc strikes between the two main electrodes. The main arc radiates the intense visible light which we see. The time delay as the pressure builds in the arc tube represents the warm-up period characteristic of all HID lamps. Similarly, a HID lamp cannot restart until the lamp cools.

In dealing with all lighting technologies, two important parameters are used to measure the quality and efficiency of light sources: Colour Rendering Index (CRI) and Efficacy. CRI indicates the effect of a light source on the colour appearance of objects. The CRI has a value between 0 and 100 and CRIs in the range of 75 - 100 are considered excellent, while CRIs from 60 to 75 are considered good. Efficacy is a measure of the efficiency of a light source and is defined as the ratio of the light output (lumens) to the energy input (watts). HID lamps have the highest efficacy values of all lighting technologies.

The HID Family

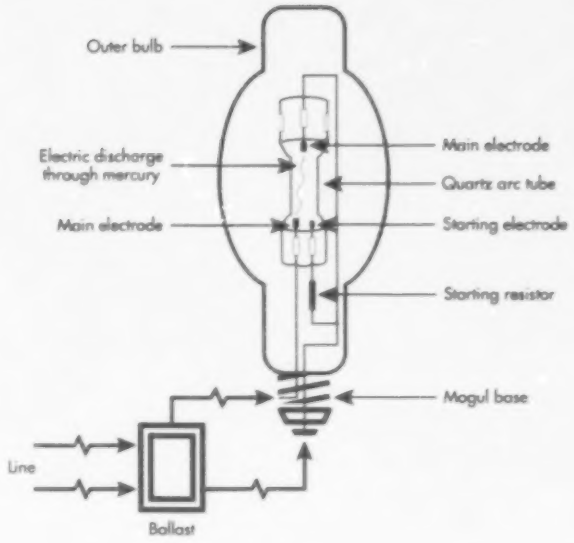
High Pressure Sodium Lamps are the most efficient and economical of the HID family. They produce a "golden-white" light and are available in clear, diffuse-coated and improved colour variations. The clear and diffuse-coated lamps have a CRI of approximately 32. The improved colour lamps yield a higher CRI value of 70 but have a lower lamp life and reduced efficacy because they operate at increased pressure. The range of efficacies for high pressure sodium lamps is 50 to 140 lumens/watt, and lamp life is typically 24,000 hours. HPS lamps have the shortest warm up and restrike times of all the HID sources requiring only 3 minutes to start and 1 minute to restrike. The

availability of 35 to 50 watt HPS lamps provide a superior alternative to the popular 150 watt incandescent PAR downlighting system. They are four times more efficient and can last up to six times longer. Being a point source they offer good optical control and can be used for highlighting. They tend to be used in applications where colour is of less importance. Clear lamps are used in street lighting, floodlighting and industrial applications. Coated lamps are used in area/floodlighting, security lighting, industrial and commercial indoor lighting and parking lot applications.

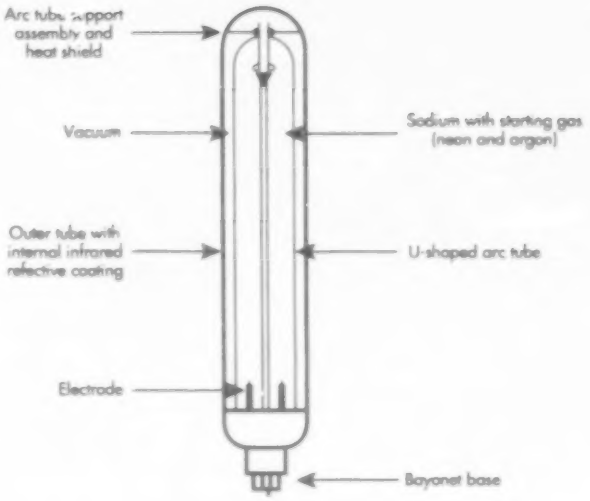
Metal Halide Lamps are the most efficient "white light" source, with an efficacy of about 50 to 110 lumens/watt, and also come in clear and phosphor-coated varieties. The clear lamps produce a slightly bluish-white colour at a CRI of approximately 65. The phosphor-coated lamps produce a warmer light with a CRI of about 70. Lamps can last as long as 20,000 hours. Common applications include area lighting, parking lot lighting, security lighting and building floodlighting. They can also be used for landscape lighting, sign lighting and walkway lighting. Because mercury vapour and metal halide lamps operate under high pressure and very high temperature, the correct fixtures must be used at all times.

Mercury Vapour Lamps were the first type of HID lamp invented. They are available in two variations: clear and phosphor-coated. The clear mercury vapour lamps give off a bluish-white light and have a poor CRI of about 22. The phosphor-coated type produce better colour rendition with a CRI of 50. In terms of efficacy, with a range of 20 to 85 lumens/watt, mercury vapour lamps are the

MV Lamps



LPS Lamps


Arc tube support assembly and heat shield
Vacuum
Sodium with starting gas (neon and argon)
Outer tube with internal infrared reflective coating
U-shaped arc tube
Electrode
Bayonet base

least efficient HID lamp and rank in between incandescent and fluorescent. Lamp life can be up to 24,000 hours. Used primarily in retail, industrial interior and street lighting applications, these lamps are currently being phased out in favour of the more efficient HID lamps such as high pressure sodium and metal halide.

Low Pressure Sodium Lamps, while not true HID lamps, are the most efficient light source currently available, with efficacies ranging from 100 to more than 220 lumens per watt. LPS lamps also differ from other HID sources in that their light source is linear (tube) rather than a point source. This makes it more appropriate where there is a low mounting height and the need for diffuse light. Lamps last an average of 18,000 hours. LPS lamps can be re-lit in less than one minute, suffer no loss of light output over their life, and can operate in very cold temperatures. They produce yellow monochromatic light, and make everything appear either yellow or muddy in colour. Colour rendition produced is so low that a CRI value has not been assigned, and use of these lamps is restricted to road lighting, security lighting, area floodlighting and warehousing applications where colour rendering is not important.

Comparison table between different HID Fixtures

	Rated Average (hours)	*Life Sizes (watts)*	*Efficacy (lumens/watt)*
Mercury vapour lamps	24,000+	40-1,250	10-63
Metal halide lamps	10,000-20,000	32-1,500	50-110
High pressure sodium lamps	24,000	35-1,000	50-140
Low pressure sodium lamps	14,000-18,000	18-180	100-220+

EXAMPLE

Consider the following replacement examples. Assume 4,000 hours of operation per year and an electricity rate of 8¢/kWh.

Replace existing 500 watt Incandescent lamp with 100 watt High-Pressure Sodium lamp plus 35 watt ballast.

Watts saved = 365
% Energy savings = 73
Annual savings per fixture = $116.80

Replace 2 x 400 watt Mercury Vapour lamps plus 80 watt ballast with 400 watt High-Pressure Sodium lamp plus 75 watt ballast.

Watts saved = 405
% Energy savings = 46
Annual savings per fixture = $129.60

For further information please contact:
Industrial, Commercial and Institutional Programs, Natural Resources Canada,
580 Booth Street, 18th Floor, Ottawa, Ontario K1A 0E4, Fax: (613) 947-4121

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ENERGY EFFICIENCY

OCCUPANCY SENSORS

Occupancy sensors, commonly used as motion detectors for security systems, are now being used with lighting control systems to save electricity. By activating the lighting system only when human motion is detected, these automated control devices lower energy costs by reducing the time a lighting system operates. They also offer additional convenience by eliminating the need for manual operation of the lighting system.

Sensor Technology — How it Works

An occupancy sensor detects and responds to motion through the use of a motion sensor and an automatic switching device. The majority have either infrared or ultrasonic motion sensors which may be equipped with an **override switch***, a **signal sensitivity*** adjustment and a **time delay*** adjustment.

- *Infrared motion detectors* respond to heat. They sense changes in patterns of heat radiated by objects that are warmer than their surroundings, such as a person walking across a room. They are passive devices that only receive a signal from within a particular line of sight.
- *Ultrasonic motion detectors* sense motion with ultrasound. These are active devices since they send out an inaudible tone, which is capable of bouncing off walls and around corners. The returning tone is compared with the tone originally sent out, and any change in the tone's frequency indicates motion in the controlled space.
- Some occupancy sensors rely on both infrared and ultrasonic signals to turn lights on. In these sensors, usually only one signal is required to maintain the lights on.

Occupancy sensor lighting control systems are available in two different configurations: a *wall-switch occupancy* sensor and a *ceiling- or wall-mounted unit.*

An ***override switch** allows the automatic switching device to be overridden and maintained in an "off" position through manual operation. The manual "off" control allows one to turn out the lights even when the room is occupied, as might be required for activities such as viewing audio-visual presentations.

A ***signal sensitivity** adjustment allows one to vary the size of the area covered by the motion sensor and the amount of motion required to activate the sensor.

A ***time delay** adjustment allows one to vary the amount of time it takes before the sensor turns the lights off. Typical settings range from five to 12 minutes.

Wall-Switch Occupancy Sensors

Wall-switch occupancy sensors replace existing wall-switches and do not require new wiring. They usually rely on infrared motion sensors which have limited fields of view and typically cover up to 50 square meters (500 square feet) of floor area. As a result, wall-switch units are best suited to small enclosed spaces, such as small classrooms, meeting rooms, storage rooms, dressing rooms, computer rooms, individual offices and small lobbies.

Ceiling- and Wall-Mounted Units

A ceiling- or wall-mounted system consists of a remote motion sensor connected by low-voltage control wires to the automatic switching devices controlling the power supplied to the lights. These systems may contain infrared or ultrasonic motion sensors mounted on the wall or ceiling to optimize the field of view. The sensors typically cover up to 225 square meters (2,250 square feet) of floor area and are best suited to large open areas such as large classrooms, partitioned office space, gymnasiums, warehouses, banquet rooms, corridors, cafeterias and lobbies.

Advantages of the Technology

Savings in electricity costs

Occupancy lighting control systems may provide significant savings in energy costs. About 40 per cent of the electricity used in commercial buildings is for lighting and sometimes as much as 50 per cent of it is used to light unoccupied space. By turning off lights when they are not needed, occupancy sensors provide savings in two ways:

- Direct savings due to reduction in electricity demand and consumption for the lighting system itself.
- Indirect savings from reducing air conditioning load. Since the lighting system operates for fewer hours, a building's internal heat gains are reduced and its cooling load decreased. (Heating loads may also increase, but it is better to heat a building with a boiler than an electric light).

Retrofit Considerations

To properly evaluate and adapt an occupancy sensor control system to an existing lighting system, several issues should be considered. Selecting an occupancy lighting control system depends on such factors as the dimensions of the controlled space, the occupancy load in the space, and the lighting load.

1. Potential for reduced lighting load

The potential for reduced lighting load determines whether an occupancy-controlled lighting system is viable. The greater the lighting load being controlled, the more cost effective the installation of these controls becomes.

Similarly, the longer the amount of time that the lights are normally left on when not required, as measured by the **control credit***, the greater the opportunity for savings. If continuous illumination is required, or the space is not vacant for periods longer than 15 minutes at any one time, occupancy sensors may not be justifiable in terms of energy savings.

The ***control credit** is the percentage of time that the lights would be turned off by the occupancy sensor, divided by the total amount of time that the lights would normally be left on (without any control system). Additional information on control credits is available from experienced lighting contractors, manufacturers or consultants.

2. Type of lighting

Fluorescent and incandescent lamps

On/off occupancy sensor systems work best with fluorescent or incandescent lighting

systems. Although people sometimes worry that switching a fluorescent lamp on and off will decrease its life, this is not really a concern. Although switching a fluorescent lamp off for short periods of time may reduce the number of hours that the lamp will burn, the extra energy cost for operating the light is more significant than the loss in burning hours, especially now with the rising costs of electricity and longer lasting lamps. In some cases, operating the lights for short periods of time may in fact increase the effective life of the lamp.

Example

A standard fluorescent (F40) lamp operating for three hours at a time and burning for 3,500 hours per year will have an effective life of 5.7 years. If the same lamp were operated for only 30 minutes at a time for a total of 1,750 hours per year, it would have an effective life of eight years. In this case, leaving the light on for only short periods of time may have decreased the lamp's total number of burning hours, but its effective life was increased due to fewer hours of operation per year.

High intensity discharge (HID)

Occupancy sensors are not as suitable for high intensity discharge (HID) lighting, such as metal halide, mercury vapour and high pressure sodium lamps. In particular, HID lamps should not be turned off unless the shut off period is longer than 30 minutes. Rather than completely turning off the lamp when the space is unoccupied, the HID lamp's special ballasts operate the lamp at a reduced light output (about 35 per cent of the power) and instantly turn on the lamp when the sensor indicates occupancy.

3. Selection and placement

When selecting the type and number of occupancy sensors to install, be sure to consider not only the amount of area covered by the motion sensor, but also the shape of the area, be they circular, elliptical, fan shaped or rectangular. Ceiling height also affects the number of sensors required for ceiling-mounted systems. As the ceiling height increases, fewer sensors are required.

False triggering is another factor to consider when selecting a sensor and determining its placement. Infrared sensors may be triggered by a mirrored image, heat vents, baseboard heaters or daylight. Ultrasonic sensors may be triggered accidentally by building vibration or other non-human sources of motion. Usually the sensor's sensitivity can be adjusted to reduce or eliminate false triggering. Another solution is to use sensors that combine both infrared and ultrasound for sensing motion. Manufacturers provide installation instructions on how to avoid false triggering.

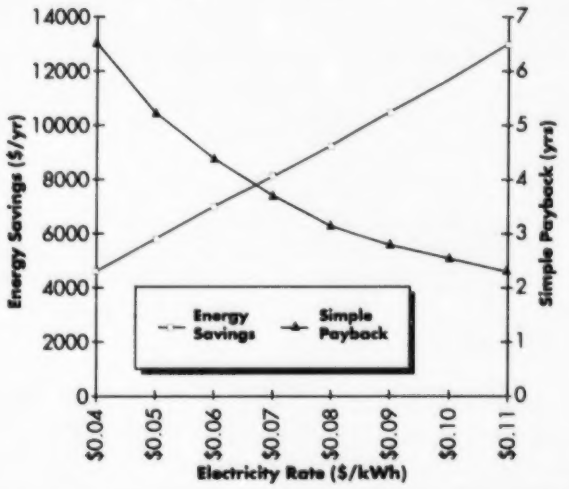
Example of savings

A building has 30 small offices with three fluorescent fixtures per office and open office space with 910 fluorescent fixtures. The lighting systems normally operate 4000 hours a year. It was determined that 30 wall switch units are required for the individual offices and 100 ceiling-mounted sensors are required for the open office space. Each fixture contains two standard T12-40 W (F40) fluorescent lamps with a standard ballast and consumes 96 Watts (or .096 kW). A control credit of 35 per cent is assumed for the wall switch units and 30 per cent for the ceiling-mounted systems.

Figure 1 shows the amount of savings which can be achieved by installing occupancy sensors in this building. The following equation was used to determine the annual energy savings for the lighting system.

Annual Energy Savings ($/year)	=	Control Credit (%)	x	Number of Fixtures	x	Kilowatts per Fixture (kW)	x	Hours of Operation (hours)	x	Electricity Rate ($/kWh)

Figure 1 - Annual Lighting Energy savings and Simple Payback for installing occupancy sensors in the example



The higher the electricity rate, the greater the savings. In 1993, commercial customers in Canada were paying between $0.045 to $0.11 per kilowatt-hour (kWh) of electricity, including taxes and demand charges. In other words, in this example, occupancy sensors would provide between $5,000 and $12,000 of savings per year.

If the wall-switch units cost $110 each and the ceiling-mounted sensors cost $270 each, the capital cost would be $30,300 and the simple payback would be calculated as follows:

Simple Payback (years)	=	Capital Cost ($)	÷	Annual Energy Savings ($/yr)

As shown in Figure 1, the simple payback period varies from 2 to 6 years, depending on the electricity rate. It must be realized that simple payback calculations should only be used to estimate the potential for savings. To properly evaluate systems, a complete life-cycle analysis should be conducted which would include the capital costs, operating and maintenance costs (including savings due to a reduction in the air conditioning load) and interest rates, as well as any financial incentives offered by local utilities.

For further information, please contact:

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